ATO

Modeling Tracking and Tracing in Food Chains

Evaluation of the TraceTool modeling-method

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Confidential

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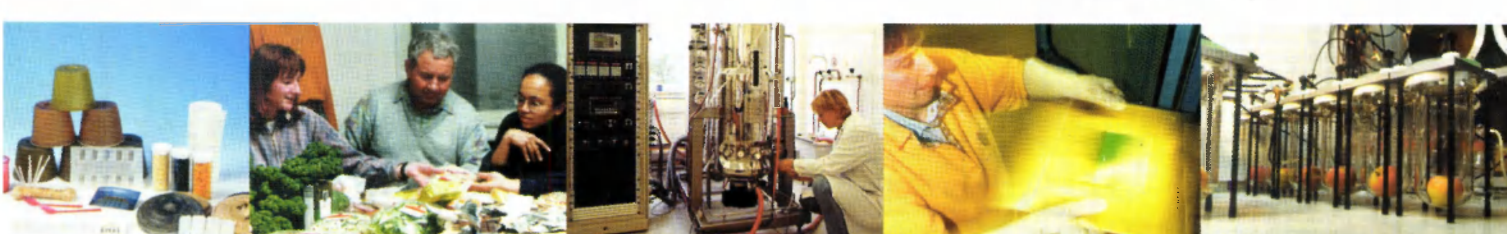

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Summary

Companies in food chains establish a Tracking & Tracing (T&T) system for various reasons. The main reason for companies to implement T&T systems is that governments want these T&T systems to guarantee food safety. TraceTool is a modeling method that can be used to build models of T&T systems. The overall objective of this research was to evaluate TraceTool. The method we used to evaluate TraceTool was to design models of T&T systems of two cases, using the modeling language defined in TraceTool. Subsequently improvements to these models were designed, based on virtual demands of companies. It appeared to be possible to model both cases and to analyze the chains for bottlenecks. Also it was possible to design improved T&T systems. We were successful to contribute to the evaluation of TraceTool, by modeling the two cases. However, it is advised to model more cases in the future to come to a more solid modeling method. Also, taking into account real client's demands would make TraceTool more truthful.

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1. Introduction

This chapter describes the research introduction. First, the research object is discussed (section 1.1). Secondly, the problem definition of this report is given (section 1.2). The problem definition leads to the objective of this report (section 1.3). To answer this objective, main research questions (section 1.4) and sub-questions (section 1.5) are posed. The research method we will pursue during this research is given (section 1.6). To conclude the first chapter, a overview is given of the contents of the report.

1.1 Research Object

The research object is "tracking & tracing systems in food supply chains." In this report the following definition is used of Tracking & Tracing (in this report abbreviated to T&T): the term *tracking* is used for the collection of techniques and instruments that register where the product currently is in the chain. *Tracing* states the route the product has gone through in the chain and registers the activities that had impact on the product (Vogels *et al.*, 2002). A T&T system is an information system that keeps track of product routes and thereby supports tracking and tracing (Moe, 1998).

1.1.1 Background

T&T systems are well known in the area of transportation. For example in courier-companies, where T&T systems are used to register the courier's position and guide him or her to the destination-address. T&T systems that are used for product safety purposes are developed mainly in the pharmaceutical area. From there, T&T systems became also in use in the food industry. With the increasing implementation of Good Manufacturing Practice (GMP) and ISO 9000 quality management in food manufacture, T&T systems have become more advanced covering more information and more steps in the production chain (Moe, 1998). In an ideal situation, all products originate from a trusted and identified source and run through a certified and transparent channel. However, according to Trienekens (2001), the situation in the food sector is far from ideal. It is estimated that millions of Europeans get sick every year from food contamination. A research project carried out in 1998 by the European Commission showed that 11% of all food products that are controlled in the EU do not comply with the demands of EU legislation. Since the discovery of BSE in cattle as the probable cause of the for humans deadly variant Creutzveldt-Jacob, there has been a crisis in the European cattle sector (Trienekens, 2001). This situation intensified after the outbreak of mouth and foot disease in Europe. The possibility to repeatedly end up in such a crisis is increased by the severe degree of concentration in the food sector and growth of international trade in livestock and food products. These developments stimulate the spread of animal-infections (Trienekens, 2001). T&T is an instrument that may contribute to escape from the undesired situation in the European food sector. To display the possibilities of T&T, we give an overview of the main reasons to implement T&T in food supply chains.

- **Meeting current and future government requirements**

Governments see the need of greater visibility of the product and information flows in food supply chains to guarantee food safety. With a T&T system it can be proven which raw materials were used for the product and which activities had an impact on the product during its route in the production process. When something appears to be wrong with a product (e.g. a contamination with Salmonella) at a certain moment and place in the production chain, a T&T system can help to find both the cause of the problem and the other contaminated products. In the nearby future, legislation on the identification of food products in food supply chains will be extended. To comply with the new demands, companies are forced to introduce sophisticated information systems that focus on identification, registration and tracking and tracing. For example, the EU demands that food products that contain GMO's (Genetically Modified Organisms) must be labeled as such (Trienekens, 2001). T&T can help to detect the source of these GMO's. Other examples or initiatives supported by government legislation are Eurep GAP and ISO 9000. Eurep GAP comprises demands that certify the food supply chain to produce environment-friendly, safe and high-quality products. T&T systems include more extended functionality than Eurep GAP prescribes. T&T not only certifies a specific channel, but it can prove the channel to be reliable as it identified products and the route that is traveled by these products through a channel. In this way a T&T system can guarantee a product's origin and composition, by tracing back earlier stored information.

- **Efficient recall management**

As stated before, a T&T system can be used to discover the origin, composition and specific activities that had an impact on the product. On the basis of this knowledge companies in the food sector can decide to make efficient small recalls of only the products that had undergone the same treatment as the contaminated product or made contact to this product. T&T is a firm basis for efficient recall procedures to minimize loss of money and reputation in food supply chains (Moe, 1998).

- **Enhancement of marketing possibilities**

T&T can guarantee the origin and quality of a product. Chain members can assure the origin and safety of their product to the consumer. Information about the origin of a product and certain activities that had an impact on the product can be sold along with the product. This kind of functionality can be interesting from a marketing point of view (Moe, 1998). For example, marketing can be based on a certain product-feature such as the biological production method of a product. Pointing out in advertising this distinctive product-feature can be used to attract certain consumers. T&T can help to acquire consumer's confidence in these food products and it can mean a boost for the image of the companies in the food supply chain. According to Boerrigter (2002), a T&T system can strengthen the bargaining power of manufacturers of fresh produce when they can assure to the other companies in the chain and to the consumer the quality and reliability of their products. Right now manufacturers feel that they have a disadvantage. For example, growers have to comply with regulations like Eurep GAP (Good Agricultural Practice), while retailers are not impaired by such regulations (Boerrigter, 2002)

- **Flexibility of the food supply chain**

The functionality of T&T systems that enables companies to make efficient recalls of products is of special importance to the flexibility of the current food supply chains. For example, in a pear chain, a retailer has only two to three suppliers of a certain product. When one of these suppliers has a problem with a product, the retailer is as a consequence low on supply. A T&T system can help to find the cause of the problem and thereby determine which products are affected by this problem. Effective recalls can be made of products that were impacted upon by this problem. In this way a T&T system helps to quicken the return of the supplier back into business and thereby contribute to the flexibility of the chain (Pladdet, 2002). Another type of flexibility that can be attained using a T&T system is the flexible use of lines of production when processing food products. For example, when a T&T system is established for all food products, there is no need to distinguish between a line of production for biological products and a line of production for 'normal' products. This is because information about the origin and composition of products is registered for all products and using this information, products can be individually identified as to be biological or non-biological.

1.1.2 Scope of T&T

With respect to T&T in food supply chains there are gradations to what scope T&T is used. T&T systems in food industry can be limited to a single company or be extended to include multiple companies in a food chain. In this research project we focus on T&T systems that cover whole or part of the food supply chain from manufacturer to the consumer. We consider multiple companies in supply chain, to be able to analyze difficulties that can arise when different companies are working together in a chain. Such difficulties might be worth wile studying in this research. For example it is interesting to study whether traceability can be guaranteed when multiple companies are involved or that the T&T system companies use remains limited to the own company-boundaries.

Furthermore, a T&T system consists of both a product flow and an information flow. The information that is part of this information flow can be concise or extended varying per T&T system. (Moe, 1998). We distinguish the two following aspects that make up the information that is registered in the information flow in a T&T system. The first aspect in to be able to determine at every moment in the chain *where the product* is in the chain. The second aspect is to register *all the external factors* that change in the supply chain. In the following we will discuss what both aspects imply.

Determining where the product is at every moment in the chain

This aspect of a T&T system implies that products have to be identified while traveling through the chain. This aspect is referred to as making it possible to tell a product's location at a certain moment in time and as a consequence to be able to discover its history through whole or part of a chain. Types of questions that may occur during monitoring and control of the process are the following. Where is the product? Where has it been, at any moment in time? Is it necessary to make adaptations in the routing of a batch or even conduct a reorganization of the logistic pathway as a whole? (Verdenius *et al*, 2000). These questions can only be answered if sufficient information is registered at all points in the chain. Also the information gathered at any point in the chain should be linked with information, gathered at previous points in the chain.

Registering the external factors

External factors help to define the scope of the T&T system. This aspect is referred to as registering the change in external factors that occurred in the chain. Types of questions that may occur during these activities are the following. Which production steps have an impact on the product? What raw materials were used? What were the production conditions? (Verdenius *et al*, 2000). To answer these questions, external information is registered, since external factors can influence the product. When external factors have caused a problem at a certain point in the chain, a T&T system it expected to help to find the problem and all products that are affected by this problem.

In this report a choice is made to focus on information relevant to T&T. Thereto in the first place it is important to include information in the T&T system that takes into account the first aspect of a T&T system; determining where the product is in the chain at every moment. On top of that we included the second aspect of the necessary information to T&T; describing environmental factors that influence the product in the chain. This choice was made, since it is important for companies in the food supply chain to be able to track the product throughout the chain as well as to be able to connect to detailed environmental information to guard product quality. However, quality-oriented T&T is a step further. Quality-oriented T&T includes, for example quality-degrading models that predict the quality-loss of products when exposed to a certain temperature during a certain time. Even though temperature and time are included in models that we build during this research, the model that predicts the influence of temperature over time itself is not included. Nevertheless, in the future the scope of information registered in our models can be extended as required to include more descriptive factors (Moe, 1998), also to include a quality-degrading model. To include more descriptive factors, information about these factors has to be added to information about external factors that change over time in the chain. Moreover the companies that use the T&T system determine the scope of information that is included in the model. For example, when a company aims to make efficient recalls. This aim can be achieved either on basis of a minimum of information or more extended information. The minimum of information can be a production date, however the more information that is included, e.g. production time, batch numbers or production conditions, the more precise a recall can be. The functionality of a T&T systems depends on the demands companies in the food supply chain have on the behavior of a T&T system.

1.1.3 Tracking and tracing within the ATO-context

Within the framework of the developments of emerging T&T systems in the food sector the Agrotechnological Research Institute (ATO) in Wageningen, developed a modeling-method, called TraceTool, describing a concept for systematically modeling T&T systems in food supply chains. In short the TraceTool modeling-method functions as follows.

- The product and information flows in these two selected cases at the current situation are described and then modeled, using the modeling language in TraceTool.
- Improvements to these chain-specific models, reflecting the current situation, are made in an iterative improvement process.
- Improvements to the models are made based on client's demands to come towards models reflecting the desired situations for both chains.
- Based on models representing a desired situation, recommendations might be made to improve the information flow and process configuration of the T&T systems in practice.

TraceTool is described into more detail in chapter two. The primary focus is to analyze T&T systems that cover whole or part of a chain, to be able to analyze difficulties that can arise when different companies in a chain have to work together. We focus on the aspect of a T&T system to map the route of a product, but also take into account the external factors that change in the chain.

1.2 Problem definition

Companies are supposed to implement a T&T system because of reasons listed in section 1.1.1. Implementing a T&T system could be done by designing a T&T system from scratch and bring the T&T system into effect in practice. We can also give preference to a more careful approach. A careful approach implies that it is necessary to build models as a representation of real T&T systems and study it as a surrogate for the real T&T system. Modeling T&T systems is to attempt to change the functionality of a T&T system, without having to deal with the consequences of such a change practice. Considering the above we choose the careful approach of modeling T&T systems. Thereto we use the TraceTool modeling-method that is under development at ATO, because little alternative research is conducted to model T&T systems. Some articles relate to the subject but the TraceTool modeling method is more complete and therefore we want to use TraceTool to model T&T systems. Still little is known about the usefulness of TraceTool.

To study the usefulness of Tracetool we must first know what this method implies. Therefore, the possibilities of the modeling-method have to be studied. TraceTool contains of three main elements that we want to evaluate.

(1) A standardized modeling language or ontology of a logistic chain process
(2) Demands of the client
(3) Simulation of modeled chains

In short these elements imply the following:
The modeling language (1) describes the product flow and information flow in a T&T system. Products enter the (food) supply chain and go through different phases. Information about the external factors that may influence the product in a phase is registered. After each phase information about the previous phase and the impact this phase had on the product is registered and kept in an information object. Product can be identified and followed through the chain by linking the information registered at a certain moment in the chain to information registered a previous moment in the chain. This modeling language is used to make formal and unambiguous model of T&T systems. The second main element of TraceTool we want to study is whether T&T can address to demands of clients (2). Therefore we have to take into account the demands of the clients and to study the implications these demands have on the models of T&T systems. Thirdly, it has to be studied whether simulation can facilitate the evaluation of TraceTool. Further explanation of the modeling-method TraceTool follows in chapter 2.

In this research project we want to study whether the TraceTool modeling-method can help us to model T&T systems, efficiently and effectively. Summarizing, the problem definition of our research project is as follows:

It is unknown to what extent the TraceTool modeling-method can help to model T&T systems.

1.3 Objective

The objective of this research project is:

To further develop and evaluate the TraceTool modeling-method by testing the use of the method in two selected food supply chains. The sub-objective is to simulate models to facilitate the evaluation of TraceTool.

1.4 Main research questions

In order to achieve the objective of this research project, we distinguish a number of research questions.

1. **How are T&T systems described? What are the problems that often occur in T&T systems?**

   The first main research question is needed to describe the cases we use to evaluate TraceTool. We interview experts and company-people and read reports about how T&T is applied in specific cases, to describe T&T systems in two cases. While describing the T&T systems we pay attention to problems that might occur. This main question is further specified into sub-questions in section 1.5.

2. **Is it possible to describe the two selected chains using the concepts of the modeling language, defined in TraceTool?**

   Two selected cases are modeled using the modeling language, which is an element of TraceTool. We model the current production process and information flows of two selected cases in the food supply chain. Output of the second research question are chain-specific models representing two currently used T&T systems, described in TraceTool concepts. While describing the models, the modeling language in TraceTool is further developed and evaluated.

3. **What are the conclusions we can draw with respect to the evaluation of TraceTool out of testing the models, described in concepts of TraceTool, in an iterative way?**

   TraceTool is further evaluated by modeling the two selected cases in an iterative improvement process. While carrying out this iterative improvement process, the way business goals are determined is evaluated. Furthermore, it has to be studied whether TraceTool can contribute to making recommendations to improve the information flow and process configuration in practice. It has to be studied also to what degree simulation can be used in order to evaluate TraceTool. This main question is further divided into sub-questions in section 1.5.

1.5 Sub-questions

The main research questions lead to the following sub-questions when we divide the main questions in keywords and elaborate on them in sub-questions.

Sub-questions to the first main research question are the following.

- Which production steps does a product go through in certain food supply chains?
- Which information is registered by the different parties in the food supply chain during the production process?[1]
- What problems, bottlenecks occur in T&T systems?

Sub-questions to the third main research question are the following.

- Which are the possible demands of the clients?
- In what way are these demands of clients determined?
- Which adjustments were made to the models, described in TraceTool modeling language?
- What was the usefulness of TraceTool in making adjustments to these models?
- Which recommendations (to improve the information flow and process configuration in real-life chains) do these adjustments lead to?
- In what way TraceTool contributed to making these recommendations?
- In what way simulation facilitates the evaluation of TraceTool?

[1] We focus on information that contributes to the traceability throughout the food supply chain.

1.6 Research method

This section describes the research method we pursued evaluating TraceTool. The TraceTool modeling-method is evaluated by applying the method to two selected supply chains. First the product flow and information flow of the two selected cases, which are the pork and the pear chain, are described. The cases are modeled using the modeling language (ontology), which is an element of TraceTool. Based on the modeling-experience we might find out to what degree we succeeded in modeling the functionality of the T&T systems or that we have to conclude that the functionality of the modeling language has to be extended with new concepts. Also we beware of problems in current T&T systems that might become visible during modeling the currently used T&T systems. Then it is time to determine business goals clients have that lead to requirements clients have upon a T&T system (section 3.2). Evaluating TraceTool we question the way of determining these business goals. The client's requirements are used to adjust the initial models to come to a desired situation. We question to what extent TraceTool can lead to recommendations to improve information structure, process structure or business goals. Simulation is intended to facilitate the evaluation of TraceTool and in this research the need to simulate is questioned.

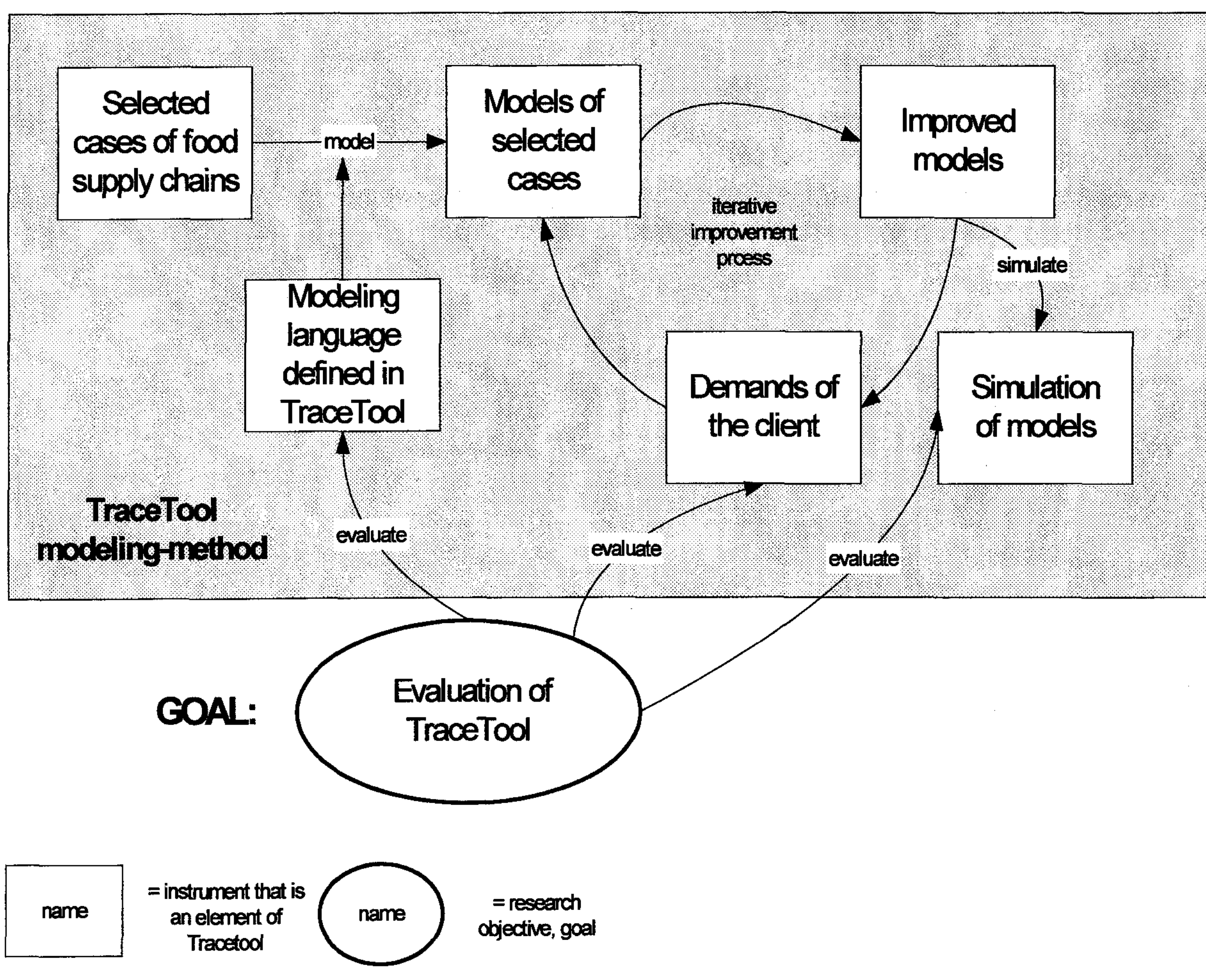

Figure 1.1 Schematic representation of the research method

1.7 Overview of the report

The contents of this report are as follows. Chapter one represents the introduction, containing the research object of this research, the problem definition, objective, research questions and the research method. Chapter two describes the TraceTool modeling method and the modeling concepts used in this method. In chapter three TraceTool is applied to model two selected food supply chains to evaluate TraceTool. Chapter four expands on simulating T&T systems. In chapter five there is room to evaluate TraceTool, followed by conclusions and recommendations in chapter six. Chapter seven contains the references. The Appendix contains Figure of the models we designed during our research project.

2. Description of the Modeling Method

The subject of this chapter is the TraceTool modeling method that is evaluated in this report. First, the way the modeling method functions, is discussed (section 2.1). Secondly, the modeling language is defined that is used in the modeling-method (section 2.2). Then short introductions to the two selected cases are given (section 2.3). After that, information that is registered inside IO's and PIO is looked into in more detail. (section 2.4).

2.1 TraceTool in detail

First we model T&T systems that are currently used in two selected food chains. To describe the current situation, we read reports, interviewed company-people and consulted experts at ATO. As a result of this we intend to describe for both food chains the product flow and information flow that together form a T&T system. The two selected chains are the pork chain and the pear chain. Subsequently, these chains are modeled using with the modeling language or ontology that is an element of TraceTool. Improvements to these initial models are made in an iterative way based on the demands of the companies. These demands should arise from strategic business goals of companies. Companies (clients) in the food supply chain can have certain specific business goals. To take into account these business goals in modeling T&T systems, these goals have to be translated into requirements on the T&T system. We verify in our models whether the current T&T systems can answer these requirements. In this way we are able to detect possible bottlenecks in the T&T systems. Bottlenecks can exist when too little information is registered or in contrast when there is an information-overload. Improvements to the models are made in an iterative process of repairing bottlenecks in order to meet client's requirements. The improvements are made in an iterative way of modeling the desired situation and reflecting these models upon the current situation and requirements. There are two types of improvements. In the first place improvements are made to models representing the current situation in both chains. The second type of improvements that have to be made to the T&T system that a company should design. Improvements of this type are improvements of the information flow and process configuration. When working with the TraceTool modeling-method we restricts ourselves to making recommendations to design improvements in T&T systems. The improved models can be used as input for simulation in a software package in order to facilitate the iterative evaluation process of TraceTool. TraceTool covers the modeling of T&T systems from strategy till recommendations to improve T&T systems. Figure 2.1 illustrates the research method we followed during our research.

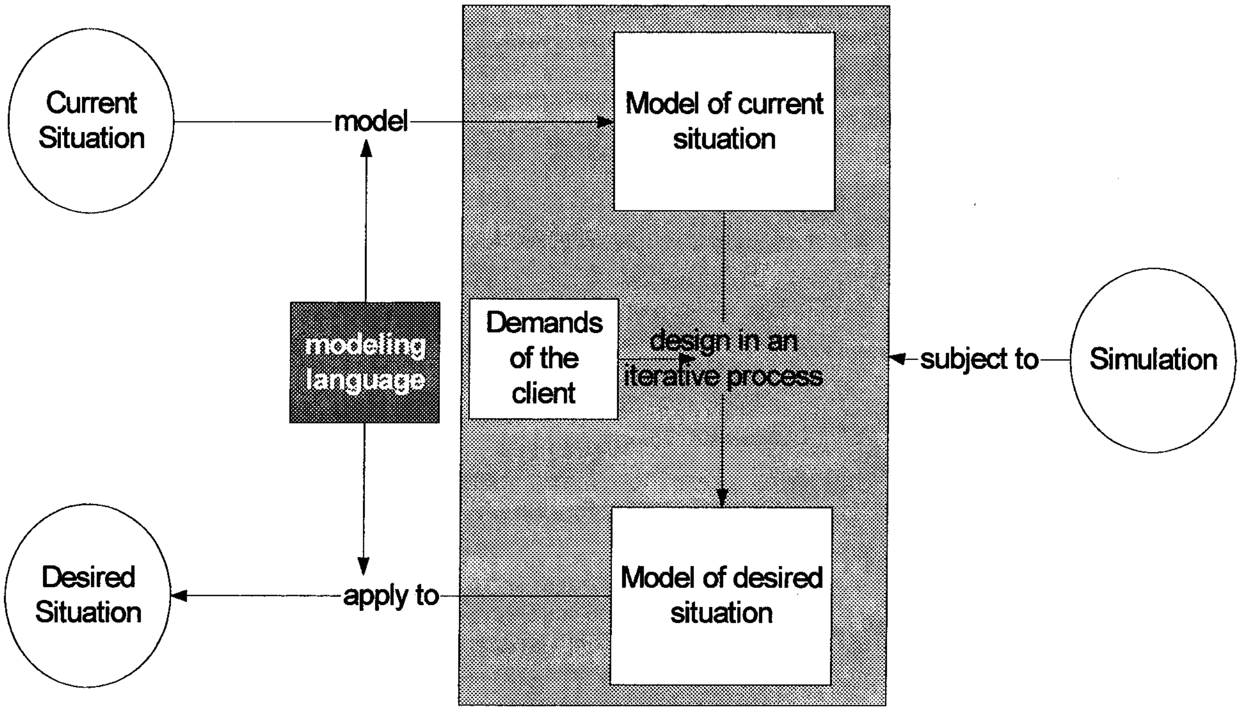

Figure 2.1 Schematic overview of the TraceTool modeling method

2.2 Modeling language

In section 2.2.1 we conduct a literature study on modeling languages. The modeling language or ontology used in this report, to model T&T systems, consists of concepts (section 2.2.2), relations (section 2.2.3) and attributes (section 2.2.4).

2.2.1 Literature study

Before we started modeling, we studied modeling literature in order to find a modeling language or ontology to model T&T systems. According to Chandrasekaran (1999), at the computer science domain ontologies aim at capturing domain knowledge in a generic way in order to provide a commonly agreed understanding of a certain domain, which may be shared and reused across several applications and among various groups of people. In other words an ontology are the concepts and relations used to describe a domain. In our case we want to use an ontology to construct models of T&T systems. Articles written by Kim *et al* and Moe *et al* were reviewed as well as the TraceTool modeling-method. Kim *et al* describe the core-aspects of a T&T system. Moe *et al* made the method of Kim *et al* more operational. The TraceTool modeling-method that was developed at ATO, connects to the methods of above-mentioned authors. In this section we restrict ourselves to discussing the analogies and differences between the modeling-methods that the authors defined.

Analogy

The most important analogy is that all authors distinguish the two following aspects as the core of a T&T system. The first is to be able to determine *where the product is at every moment in the chain*. The second aspect is the need to keep registering the *changing external factors* during a production process. External factors that can be distinguished are e.g. tools, operators or temperature that have an impact on the products that travel through a supply chain. To include these aspects in a model of a T&T system, product and external factors need to be uniquely identified. The means by what authors deal with these aspects differs among authors. Next, we represent differences that exist among the modeling-methods authors defined.

Differences

Kim *et al.,* uniquely identify a product by using the term Traceable Resource Unit (TRU), a product or a batch of products. Information about external factors that can influence the TRU are part of an 'activity' that has its impact on the product. An 'activity' is made unique by defining it to be a 'primitive activity'. According to Moe *et al.,* products are identified by type, described by e.g. species-name, variety, form or by quality attributes and by amount of products e.g. weight, number or volume of products. An activity is identified by type of activity (e.g. buying, delivering, storing etc) and by time or duration of an activity. TraceTool uniquely identifies a product by using the concept Identifiable Unit (IU). Information about external factors that have impact on an IU is implemented in modeling and accommodated in the term 'phase'. Phases are made up of a production step or a number of production steps that influence the IU traversing a 'phase'. A 'phase primitive' uniquely identifies a 'phase'. In the article of Moe *et al.,* information about the weight or volume of products is automatically included in the modeling method. In TraceTool information about weight and volume can be included in the models as it identifies a product. However this depends on the demands of the client. When the client wants information about weight to be part of the model it is included in TraceTool. In TraceTool, time or duration is used to identify a product (IU), not an activity (phase). Information about factors that influence product quality is registered in a phase and is not an attribute of a product, therefore the term 'phase' is used to identify external factors. More about the modeling language specified in TraceTool follows in section2.2. In this research the modeling language in TraceTool is subject of our study and is therefore used to model T&T systems. It provides the concepts, relations and attributes to construct models of T&T systems

2.2.2 Concepts

This section contains a representation of the terms that together describe the modeling concept of a T&T system. A T&T system consists of both a flow of products and a flow of information traversing through a supply chain. We can distinguish three categories of concepts. To begin with, the terms listed below describe the product travelling through the supply chain. Second the objects that construct the supply chain are described. Third the objects that register the information generated in the chain are described.

1. The product traveling through the supply chain

- **Identifiable Unit (IU)**

The term *Identifiable Unit (IU)* is used for the object that travels through the different phases in the production chain. An IU is the individual object that can be uniquely identified. Applied to food chains, IU's are food products in all appearances in which they transform during the production process. It may be an individual pig or a ham or even a truckload of pigs when it is not necessary for individual pigs to be identified.

2. Objects that construct the supply chain

- **Phase**

A phase represents a production step or a number of production steps in the chain, in between there is no registration of an IU. An IU travels through a phase. This phase has a certain impact on the IU. A phase is constructed of phase primitives. Figure 2.2 shows the symbol of a phase in the way it is used when modeling a T&T system.

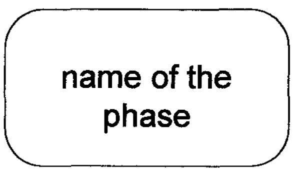

Figure 2.2 Symbol of a phase

- **Phase primitive**

A phase primitive is an activity with no sub-activities. A phase primitive is can be distinguished from a phase as it tells what happens to the IU. Therefore a phase primitive is an identifiable part of a phase and a phase as a whole is not. In models the name of the phase primitive is showed right below the symbol representing a phase, as visualized in Figure 2.3.

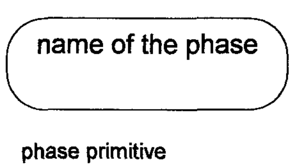

Figure 2.3 Visualization of a phase primitive in the model

The following six phase primitives are defined: source, sink, transport, storage, operation and formation.

- **Source**

The source represents the starting point from where we start to study and model the T&T system. IU's are generated in the source and after that they flow into the supply chain. What happens before a source in a real life situation is excluded from the model.

- **Sink**

The sink represents the other extremity of a supply chain: the end. IU's leave the supply chain here. Dependent on where the user of the model sets the supply chain boundaries, the sink can either be destruction or to another party in the chain. What follows after a sink in a real-life situation is excluded from the model.

- **Transport**

The IU's are transported from one location to the other. Transport represents a change in location.

- **Storage**

The IU's are stored for a certain time in an environment. Storage represents a change in time.

- **Operation**

The IU undergoes a certain operation during which the IU's internal quality is altered. Operation represents a change in status/quality of the IU. An example of an operation can be heating.

- **Formation**

In this phase primitive, an IU is either divided into pieces (dissembly) or several IU's are put together in one IU (assembly). Formation represents a change in number of IU's.

3. Objects that register the information in the supply chain

• Information Object (IO)

Information objects contain information about IU's to register where in the chain the IU together with information that links the IO to a previous IO. An IO is used to construct the information flow the IU generates on its way through the supply chain. Figure 2. 4 displays the graphical depiction of an IO.

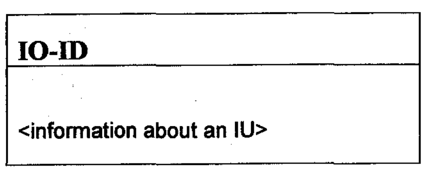

Figure 2.4 Symbol of an Information Object

• Physical Identification (Physical ID)

A physical ID is a tangible label that provides a link between an IU and an IO. It represents the aggregated information of an IO. In practice a FID is physically attached to the IU. Examples of physical ID's are barcodes, RF-chips, etc.

• Phase Information Object (PIO)

A Phase Information Object contains detailed process information about how external factors change over time. For example about what machines are used during production or what operators worked during what period using what tools. When an IU traverses a phase a PIO is created. In Figure 2.5 the symbol, which is used in the models, is depicted.

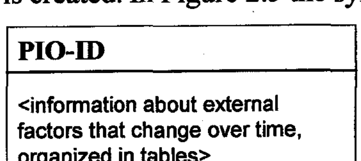

Figure 2.5 Symbol of a Phase Information Object

• Registration point (RP)

In a Registration Point, information about the IU is stored in an IO. This IO is connected to the previous IO by a pointer that is part of an IO. In an RP the physical ID is read and links an IO to an IU. Likewise a link is made to an IO in a previous RP having the same physical ID and a link is created relevant PIO's. The symbol of a RP is depicted in Figure 2.6.

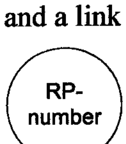

Figure 2.6 Symbol of a Registration Point

2.2.3 Relations

In the following section the relations that exist between the concepts listed in section 2.2.2 are discussed. A relation is represented by a hyphen (-).

- **IU - Physical ID**

A physical ID is physically attached to the IU. It links the information stored in an IO, about a certain IU at a certain moment in time in the information flow, to the IU.

- **IO - IU**

An IO is linked to an IU through a physical ID. An IO contains information about an IU, concerning a certain time-interval.

- **IU – RP**

In a RP information about an IU is that passes the RP is written into an IO.

- **IO - RP**

Information registered in a RP is stored in an IO, when an IU traverses a RP.

- **IO - PIO**

An IO contains among other information a link that points to the PIO that was created in the preceding phase.

- **IO - IO**

An IO contains a link that point to the previous IO in the information flow.

- **PIO - phase**

Information about relevant activities that may have had an impact on the IU during a certain phase is stored in a PIO.

- **RP - phase**

Phases are alternated by RP's.

- **Phase - phase primitive**

Phases are sub-divided into phase primitives. Each representing another kind of basic activities carried out to the IU.

2.2.4 Attributes

In this section, the information that is registered in an IO and in a PIO is discussed. Information is stored in IO's and PIO's as a list of attributes. Attributes of an IO are: (1) physicals ID, (2) a pointer to a previous IO, (3) a pointer to a corresponding phase (4) other entries. Attributes of a PIO are only entries. Entries are necessary to be able to insert information in the model. We need pointers to keep track of the information flow.

IO

An IO contains all information that is needed to track a product's route traveled in the T&T system.
Inside an IO, entries store all this required information. Entries in an IO can be RP-descriptions, times and dates. The structure of an entry looks like this: <name> description. The name-field indicates what information is registered in the record. The description contains a clarification of the information stored in the first field when necessary. Furthermore, an IO contains a pointer to a PIO that was created in a preceding phase. This pointer indicated by ^PIO. Subsequently, an IO contains a pointer to a previous IO in the information flow in the chain. This pointer is indicated by ^IO. The physical ID in an IO refers to the tangible tag that is attached to a product in the product flow of a supply chain.

PIO

Entries in a PIO contain information about the changing external factors during a certain phase. This kind of information is stored inside a PIO organized in a two-dimensional table. In this table time is registered in certain interval e.g. 5 minutes, together with information about the external factors. Information in tables can be for example the type of the feed an animal ate or the code for a workplace in a line of production. An example of such a table that in inside a PIO is given in table 2.1 (section 2.4). As mentioned in section 2.2.2, phases are sub-divided in phase primitives. This sub-division re-occurs in the contents of a PIO. Inside a PIO, information is registered concerning changes that are caused by phase primitives. For example to register information about the phase primitive transport a start-time and an end-time of transportation are registered in a PIO. This applies also to the other phase primitives. Storage requires information inside a PIO about the place of storage, the start and end-time of storage and the storage conditions. Operation requires information about the external conditions like temperature, operators or tools. Formation requires operators, tools, workplace etc. From an IO this kind information about external factors can be accessed by the link a PIO has to an IO. In a PIO it is possible to make a reference to a table e.g. a time-temperature table of storage conditions.
We represent the typical layout of the information in an IO and an PIO in the Figures 2.7 and 2.8 respectively.

IO-ID
<physical ID> description entry: <name> description pointer to corresponding phase pointer to previous IO

Figure 2.7 Information in an IO

PIO-ID
entries concerning external factors: phase description, time, conditions, tools, workplace, line of production

Figure 2.8 Information in a PIO

2.3 Selected Cases

In this research the following chains are selected to be subject to modeling.

Pork chain

The pork chain is selected because it is one of the food supply chains of which we expect that T&T can add value to the chain as it is right now. It is a complicated chain in food- and agribusiness because the chain comprises numerous production steps and formations of different products occur. It is expected to learn from the bottlenecks that we might encounter while modeling this relatively complex chain.

Pear chain

The pear chain is a chain that is widely spread in the Netherlands. That makes the chain easy accessible tby paying a visit to a company that is an actor in this chain. In this way it is to study the current situation and learn from the T&T system that is used there.

2.4 Information inside IO's and PIO's

In this section we look deeper into the information registered inside PIO's and IO's. This information is not standard in all IO's. Information inside IO's and PIO's differs per chain, because what information is registered inside IO's and PIO is dependent of the demands of the client. An example of information registered inside an IO in the pork chain can be found

IO3
<physicalID> slaughterhouse hook ID <RP description> eof slaugtering <time> time&date <PhaseID> ^PIO3 <previous IO> ^IO2

in Figure 2.9. This figure involves information linked to a slaughterhouse hook.

Figure 2.9 Example of an IO

Information inside the IO can be extended, when demanded by clients, with e.g information about weight or other product properties.

Note that in a PIO no pointers and physical ID's are included. This is because PIO do not included information that is directly related to an IU. PIO's register information about external factors that change over time and have an impact on an IU. This information is registered in tables, in which the different external factors are displayed against the time. An example of such a table, storing information inside a PIO is given in table 2.1.

time	temperature	operator	workplace
1600	12.3	Kees	100
1605	12.5	Jan	100
1610	11.9	Jan	100

3. Applying the modeling method

In this chapter we apply the TraceTool modeling method to two cases. Thereto we studied how T&T systems are applied in practical cases and what the two selected chains look like in terms of the modeling language specified in the TraceTool modeling-method. According to our research method we start with a description of the current situation. We do so by describing the current product and information flow in the pork and pear chain in section 3.1.1 and 3.1.2 respectively. After that the client's requirements (section 3.2) on both chains are given. Based on the description of both chains we model the current situation (section 3.2). After that we model the current situation of both chains (section 3.3). In section 3.4 we describe the iterative improvement process we went through modeling towards modeling the desired situation.

3.1 Description of the chains

3.1.1 Description of the pork chain

The fist chain that we selected is a pork chain in which pigs are processed into hampoles. The starting point of this chain is the farm and the chain that we consider ends at the meat processing company, at the point in time where a hampole is produced and send to the warehouse. The chain is described using information gathered from reports on the subject (Werkgroep Bestermeat KZ-ICT, 2001; Vogels, 2002), interviews with experts and using the modeling language described in chapter two of this report. Doing this we distinguish two flows: a flow of products and a flow of information through the chain. Together these flows form the basis of a T&T system. In the information flow, we focus on information that is relevant for T&T. Figure 3.1gives a visual representation of the product flow in the pork chain.

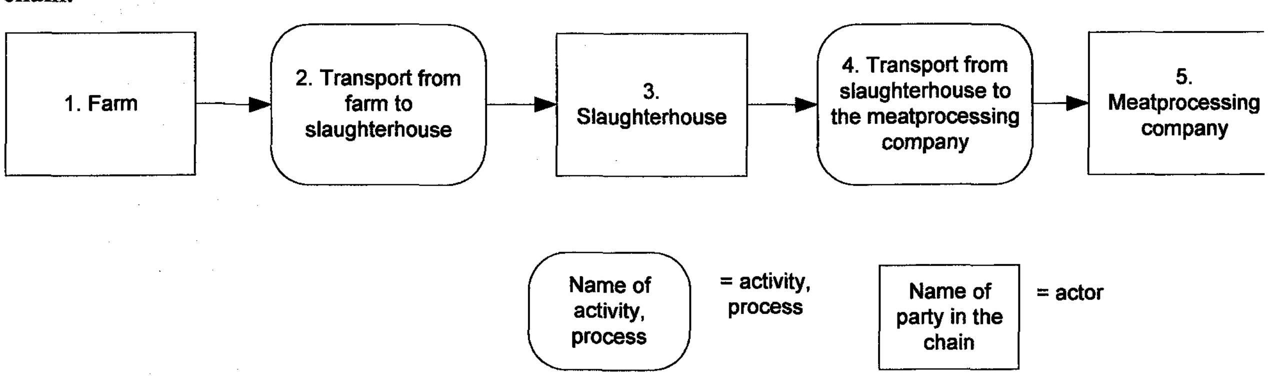

Figure 3.1 Visual representation of the selected pork chain

1. Farm

Product flow

We set the starting point of the porkchain at the point in time where piglets are multiplied at the farm. This defines the *source* of the pork supply chain. The piglets grow, are fed and medication is given.

Information flow

Information about the feed and medication is registered, when given to the pig. Before the age of 4 weeks an earmark is inserted in the piglet's ear with a UBN[2] on it. A UBN is a code that is unique for each farm or company in the porkchain. Farms, but also slaughterhouses and other meatprocessing companies have a UBN. After the age of 6 months, each pig is given an second number in the earmark that represents the order in which the pigs are transported to the slaughterhouse.

2. Transportation from farm to slaughterhouse

Product flow

A group of pigs originating from a particular farm are loaded into a truck. We note that sometimes a second group of pigs originating from another farm is loaded into the truck together with the first group.

Information flow

TruckID and the name of the driver are registered. The date of transportation together with the starttime and endtime are registered. Pigs are still identified by a UBN + serial number.

3. Slaughterhouse

Product flow

The pigs are unloaded and led into the slaughterhouse, where they are killed. Next the pigs are attached to a hook and organs and other non-consumable parts of the pig are removed. The remaining carcass is cooled in a coldstore or is directly processed. The carcass is stamped on the shoulder and subsequently chopped up into six pieces: two shoulderpieces, two midpieces (belly) and two rear-ends. Bones are removed from these three different parts and led out of our chain. The bacon fats (half-fat, half-meat) and lard and are put in separate crates. We only choose to follow hams into the rest of the chain. Other parts are left out of consideration. Hams are assumed to originate from the rear-ends and the shoulders of the pig. The hams are put together with some other hams, typically ten, in a bundle of hams. They are cooled or directly loaded into a truck to be transported to the warehouse.

Information flow

When the pigs have been killed, they are given a code written in a chip in the hook that is attached to the carcass. This code is the UBN + a serial number that determines the order in which the pigs were slaughtered. The stamp on the shoulder of the carcass contains the same code. The temperature and duration of the cooling-process are registered. The name of the operator, who cut the carcass in pieces, and the code identifying the line of production that the operator used, are registered. The remaining six parts of the pigsare processed separately. These parts are registered per production line and time of production. We note that there is no

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[2] UBN = Uniek Bedrijfs Nummer (dutch), an unique company-ID

evidence that the bundle of hams, we focus on in this part of the chain, is registered. Sometime there is a conveyor hook ID attached to the bundle of hams telling us the production date and type of product, but from this moment on hams of an individual carcass can no longer be identified.

4. Transportation from slaughterhouse to the meatprocessing company

Product flow

The bundle of hams is transported to the meat processing company.

Information flow

Trucknumber and the name of the driver are registered. The date of transportation together with the starttime and endtime are registered as well as the temperature in the truck during transportation. In the current situation information about the hams is no longer linked to information previously registered in the pork chain.
Sometimes a card mentioning the type of product and production-date is attached to the conveyer hook.

5. Meat processing company

Product flow

The incoming hams are held in a buffer and from there led into the production line where bone, lard and other inedible parts are cut of. Hams are put into a tumbler together with bacon and lard in the right proportions and processed into hampoles. After that hampoles are sliced up in different portions dependant of customer's wishes. The ham is packed and transported to the different customers: butchers, supermarkets or distribution centers.

Information flow

The temperature, pH and the weight of the incoming hams are checked. When these parameters are within thresholds, the hams are identified by a card that contains the following three items of information: first a number that represents the order of arrival, second a code that represents the kind of product and third the number of hams in a bundle. This means that there is no link anymore to the initial UBN code. A batch of hams is inserted in the tumbler. The date, start-time, end-time and size (in kgs) is registered per batch. Lard and bacon that are added to the hams in the tumbler are not identified. After tumbling and packing a barcode is attached to the ham together containing production date and time.

3.1.2 Description of the pear chain

The second chain that we selected is a pear chain. The chain is described based on information gathered from interviews recently held with managers employed at a fruit-trader and a packaging company in the pear chain. Figure 3.2 represents the product flow in the pear chain.

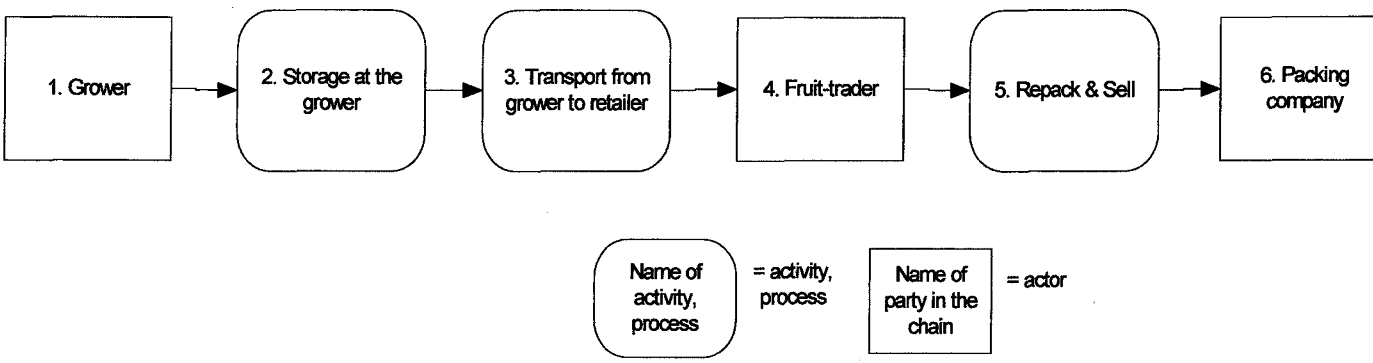

Figure 3.2 Visual representation of the pear chain

Product flow

1. Grower

We set the starting pint of the considered pear chain at the grower. The pears are grown in the orchard of the grower. The pear-trees are sprayed with pesticide. Fertilizer is added to the pear-trees. The orchard is divided into plots when pears originating from different plots have divergent quality. The ripe pears are harvested in several plucking rounds in the period from September till November. Pears that are harvested on different days of the year are treated separately. The harvested pears are put in boxes.

Information flow

The growercode and date of harvest are written on the box, that contains the pears that are harvested during that day.

2. Storage at the Grower

Product flow

The pears are either stored for a short period of time in the local coldstore of the grower or directly transported to the fruit-trader. Sometimes, pears are sorted on size and quality-class locally at the grower. Pears remain in the coldstore at the grower till the pre-arranged date of transport to the fruit-trader.

Information flow

The whole harvest of one day is given a code, unique for this particular harvest. This code consists of a code or name defining the grower, together with the date of harvest. When quality differs significantly between plots a distinction may be made between pears originating from different plots.

3. Transport from grower to fruit-trader

Product flow

The harvest of one particular day of a certain grower is called a single batch. The batch of pears is loaded into a truck and delivered to the fruit-trader to be stored there at a pre-arranged date.

Information flow

Trucknumber and the name of the driver are registered. The date of transportation together with the starttime and endtime are registered. The transport takes a relatively short time, because the pears are delivered at a pre-arranged date to the nearby fruit-trader.

4. Fruit-trader

Product flow

The boxes of a single harvest are put together with some other batches of pears from other growers, consisting of roughly the similar quality, in a ultra low oxygen (ULO) cell at the fruit-trader. The temperature of the ULO cell is around –1C and the pears can be conserved for 7 or 8 months and taken out of storage at a pre-arranged date.

Information flow

A serial number is added to the growercode, to uniquely identify the batch of pears. A serial number defines the order in which the batches of pears are stored in the coldstore of the fruit-trader. During the storage the fllowing parameters are registered: fluid extraction in liters of the pears in the cell, temperature, humidity and oxygen level in the air of the cell. The levels of these parameters are monitored and adjustments are made when necessary.

5. Re-pack and sell

Product flow

The pears are sorted to size and quality-class. Approximately 30 percent of the pears is sold at the fruit-auction. About 60 percent of the pears is sold trough negotiated-sale. The buyer can choose in what type of packaging the pears are packed. Usually the buyer buys batches pears that are of corresponding quality. A certain percentage of the pears is send to destruction.

Information flow

A blockcode is given to the collection of batches that is sold at the fruit-auction. Still it is known of what batches a block consists. Still on every pallet and every crate (a pallet is made up out of crate) the growercode is printed as well as a code name of the fruit-trader and the date of harvest, all combined in a single barcode.

6. Pack

Product flow

The pears out of the crates are packaged into smaller sized packages, destined for the consumer in the supermarket. However part of the pears is sold packed in crates and transported to the retailer.

Information flow

Pears in crates have a code mentioning the growercode and the week the pears are packed. The consumer-packages are not given a barcode. Still, it is known of which grower the pears in the package originate because the pallets with growercodes on them correspond directly to the pallets with consumer-packages. But this is not a one-to-one relation in all cases. A pallet of consumer packages may contain pears originating from different growers. That is because in between the process of packaging the consumer packages can be filled with pears of a different grower to complete the pallet of consumer packages. This pallet is called a change-over pallet. That is why the start and end time of a packaging batch are registered to know of which two growers pears are included in this change-over pallet.

3.2 Client's demands

In this section, the demands clients have with respect to a T&T system are described. The client's requirements are converted into questions that clients want to be able to answer with their T&T system. We try to find answers to these questions by modeling the implications that a number of example-questions have to the models on the pork and pear chain.

3.2.1 Client's demands on the pork chain

The management of a company in the pork chain is concerned about the issue of food safety and wants to base its marketing strategy on a T&T system that facilitates food supply chain transparency. This client's demand results into the first question that we want to be answered using the model of the pork chain.

1. Is it possible to find out from what individual pig the slices of ham originated that I bought at the supermarket today at 5 p.m.?

One client raised the issue of microbiological safety as the main concern for staying in business.

2. Which parts of which pigs have made contact to a certain contaminated hook?

One client wanted to be capable of efficient recall management.

3. How can we diminish the volume of a recall?

3.2.1 Client's demands on the pear chain

One client wanted to comply to government regulations that require the traceability of a product's origin and composition.

1. **Is it possible to find out from what grower the pears originated that I bought at the supermarket today at 5 p.m.?**

One retailer wanted to enhance the marketing possibilities of his company.

2. **Can a T&T system be used to stress the benefits of a biological production method?**

One group of clients in the pear chain wanted to run the logistical process in the pear chain more efficiently by better connecting the processes that take place in distribution center (DC) and the retail outlet to processes in companies backwards in the pear chain. The requirement of these clients is operationalized in the third question.

3. **Can a T&T system make that when a product leaves the DC or retail-outlet this is also noticed at the packing company?**

3.3 Modeling the current situation

The first step in the TraceTool modeling method is to model the current situation of two selected cases. We use the modeling language defined in TraceTool to model the chains in our cases in a formal and unambiguous way. On the basis of the description of the chains given in sections 3.1.1 and 3.1.2 we will model the current process structure and information flows in the pork and pear chain using the modeling concepts defined in section 2.2.

3.3.1 Modeling the current situation of the pork chain

Before modeling we performed a paper simulation of the pork chain to gain insights in the chain that can help to model the pork chain. We used a slice of paper that represent a individual pig. To simulate the phases in the pork chain (slaughtering, partitioning), the piece of paper is cut up into pieces that represent the different products and intermediary products that exist at a certain moment in time in the pork chain. The information that has to be kept about these products is written on these paper slices. The paper simulation gained the following insights.

Entries can consist of more than one record of information. For example a farmer can use multiple types of feed and medicine. In the PIO only the name of the external factors are given in the representations of the models. Actually inside PIO's information is stored about external factors that change over time. This two-dimensional information can be organized in tables includes the field of time and field in which information about external factors (temperature, workplace, operator etc.) can be stored. This insight is already used in section 2.2.4 that discusses the attributes of an IO.

An extra registration point is inserted in the model after the source just before transporting the pigs from the farm to the slaughterhouse, in case pigs of more than one farm are loaded into the truck. Because when pigs originating from more than one farms are put together in one single truck, registration has to take place at the farms before loading the pigs into the truck. Furthermore it is assumed that the UBN + serial number in the slaughterhouse is attached to the ham in a chip in the hook. We notice that from the moment the bundle of hams leave the slaughterhouse, all information registered earlier is lost. We use these insights to update our initial chain-specific model of the pork chain.

Models of T&T systems consist of a product flow through the supply chain, which is positioned, in the centre of the sheet of paper. The product flow consists of phases alternated by RP's. To the right of the product flow information to track the product's route through the chain is positioned, included in IO's. To the left of the product flow information about the changing external factor is position, included in PIO's. The model of the current T&T system used in the pork chain is represented in the Figures 1 and 2 of the appendix.

3.3.2 Modeling the current situation in the pear chain

The pear chain is modeled, based information about the T&T systems of two companies. This information is gathered from interviews with company-people employed at a fruit-trader and a packing company in the pear chain. The information was given to us in such a great detail, that there is no need to perform a paper simulation to help to model the pork chain. The model of the current T&T system used in the pear chain is represented in the Figures 3 and 4 in the appendix.

3.4 Designing towards the desired situation

This section describes the iterative process we went through designing models that reflect a desired situation. The process is meant to transform the models reflecting the current situation into models that reflect (or come close to) the desired situation. Input to the iterative process are demands of clients on T&T systems (listed in section 3.2). For each demand we report to what extent this question can be answered in the current situation. Doing this we intent to detect bottlenecks in T&T systems used in the current situation that prevent the company from meeting those requirements. Next we think of solutions and attempt to model these solutions to meet the desired situation. Thereto we zoom into the model of the current situation to the spot that needs improvement. This operation is repeated for each client's demand and in this way we update the models, working up to modeling the desired situation.

3.4.1 Designing towards the desired pork chain

1. **Is it possible to find out from what individual pig the slices of ham originated that I bought at the supermarket today at 5 p.m.?**

Current situation

As it is right now answering this question is not possible. Using the current T&T and with extensive re-work we are able to trace the slices ham back to a tumbler-batch, consisting of numerous hams, in the meat processing company.
Backward in the chain a major bottleneck exists, preventing the first question to be answered. The bundle of hams that leaves the slaughterhouse in some cases has no tag at all. In some cases the bundle has a tag mentioning the name of the product and date of production, but anyhow the information on the tag is not linked to what happened backwards in the chain. From this moment on all information gathered at previous moments, is lost.
Onward in the chain a bottleneck occurs during the phase of tumbling. Numerous hams are inserted together with additives, such as fat[3] to produce a hampole. Hams in a tumbler-batch originate from numerous pigs.

Desired situation

In theory we can solve the first question by printing, the UBN + serial number the pig got since it entered the slaughterhouse, on the consumer-packages of ham in the supermarket. Completely implementing this improvement in practice would take serious money-consuming adjustments. Among other things the hams in a tumbler-batch have to be downsized to contain only hams originating from the same individual pig. This will take extra production

[3] The unidentified fat is a problem that is not tackled in our research. We concentrated on the main product (ham). However, a solution to the problem might be collecting all the fat originating from an individual pig, or a group of pigs, in a crate. A tag can be attached to this crate mentioning the UBN + serial number(s) of the pig(s) involved.

time and considerable extension of data-recording equipment. What we can do to try and solve a major bottleneck in the process structure is to attach a tag or chip to the bundle of hams, e.g. in the conveyor hook that is attached to the bundle of hams. This tag has to contain information that is linked to information previously registered in the chain. It can be done to print the UBN + serial number on a card attached to an individual ham. Another option is to attach a single card to a bundle of with the UBN + serial number of the pigs processed is the hams. Improvements to repair the bottleneck that exists in the phase of tumbling have effect on the requirement to minimum the size of a recall. This problem will be addressed to in the third question.

Implications to the model

We zoom into our model of the current situation in the pork chain to see what implications the above mentioned adjustment has to this model. IO4 contains information about the bundle of hams. The physical ID of IO5 (when there is one) is necessary to identify the bundle of hams. Right now it is meaningless for T&T purposes. It only mentions the type of product and date of production. It has to contain the UBN + serial number of the pig(s) the hams originate from or a least a link to this information. Therefore we have to add a pointer in IO 4, that links the information in IO4 to the previous IO3 that is linked to IO2 that contains the information we need: the UBN + serial number of the pig. When this adjustment is applied the physical ID in IO5 is meaningful. It relates indirectly to the UBN + serial number of a carcass. Adjustments to IO4 are shown in bold italic font in Figure 3.3.

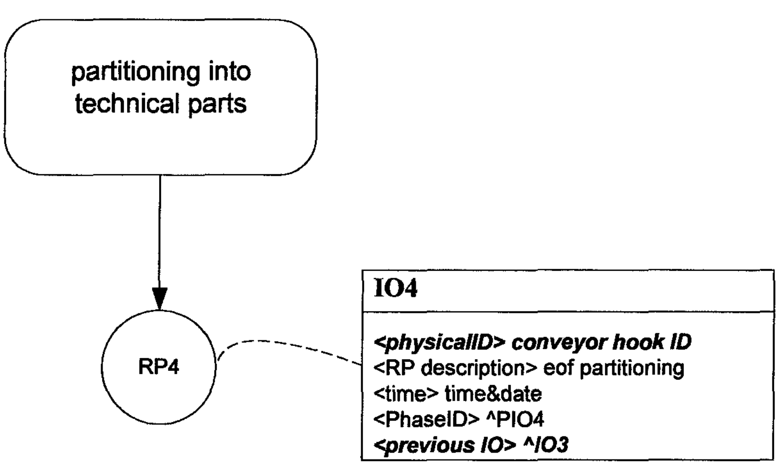

Figure 3.3 Adjustments to current model of the pork chain, based on the first question

2. Which parts of which pigs have made contact to a certain contaminated hook?

Current situation

This question draws our attention to the phase of slaughtering and removing of offal, as well as the phase of partitioning the carcass into technical parts, in the slaughterhouse. A code identifying a line of production and the name of the operator are registered, during certain moments in time. Parts of the pigs are attached to conveyor hooks that are not identified. As a result we can not tell which parts of a pig made contact to a contaminated conveyor hook.

Desired situation

To solve this problem we have to investigate where the contamination came from. There are some options: other hams, operators, machines and working places etc. Lines of production cover a large section of the company and more than one operator makes contact to a part of a pig. The current model can be improved dependent on the amount of money the client wants to invest and the amount of certainty he wants to attain. Time-periods in between registration points need to be shortened and the size of the workplace has to be reduced. Also we have to register exactly what operators and what impacted or made contact to an identifiable unit (IU), such as a part of a pig. An important adjustment is to attach a tag to all conveyor hooks in the slaughterhouse that make contact to IU's. An individual IU remains attached to the same hook all the way during the slaughtering phase. This requires discipline of the operators. In this way the link to the UBN + serial number is still valid. Furthermore, information on this tag has to be linked to information that about the slaughtering phase that impacted on the IU. Another option is to stamp the UBN + serial number on the hams and other technical parts.
To keep track of the offal a tag can be attached to the crate, the offal is put in. It is possible to identify of which pig(s) the offal originated from, using the pointers to previous IO and to the adjacent PIO, of which group of pigs the offal originates and what impacted on the offal during the phase.

Implications to the model

At first a physical ID has to be added to IO3 to identify the hook that is attached to parts of a pig. This can be slaughterhouse hook ID. We note that this is not the same ID that we use in IO4, but the two ID's are linked. IO3 remains linked to PIO3 and IO4 remains linked to PIO4. However, the information in PIO3 and PIO4 has to be extended. PIO3 needs information about the workplace, which is a part of a production line together with a frequent time registration of which operators, using what tools impacted on the IU. PIO4 needs a similar adjustment. Attributes that have to be added to PIO3 and PIO4 are workplace, time, and tools. To keep track of the offal an physical ID; crate ID is added to IO3b together with a time-registering attribute. The time-attribute helps to register the impact the activities conducted in the slaughtering phase had on the offal, during a certain period in time. IO3b is linked to IO2 to provide a possibility to trace back to the group of pigs the offal originates from. Figure 3.4 shows the implications the functionality above has to the model.

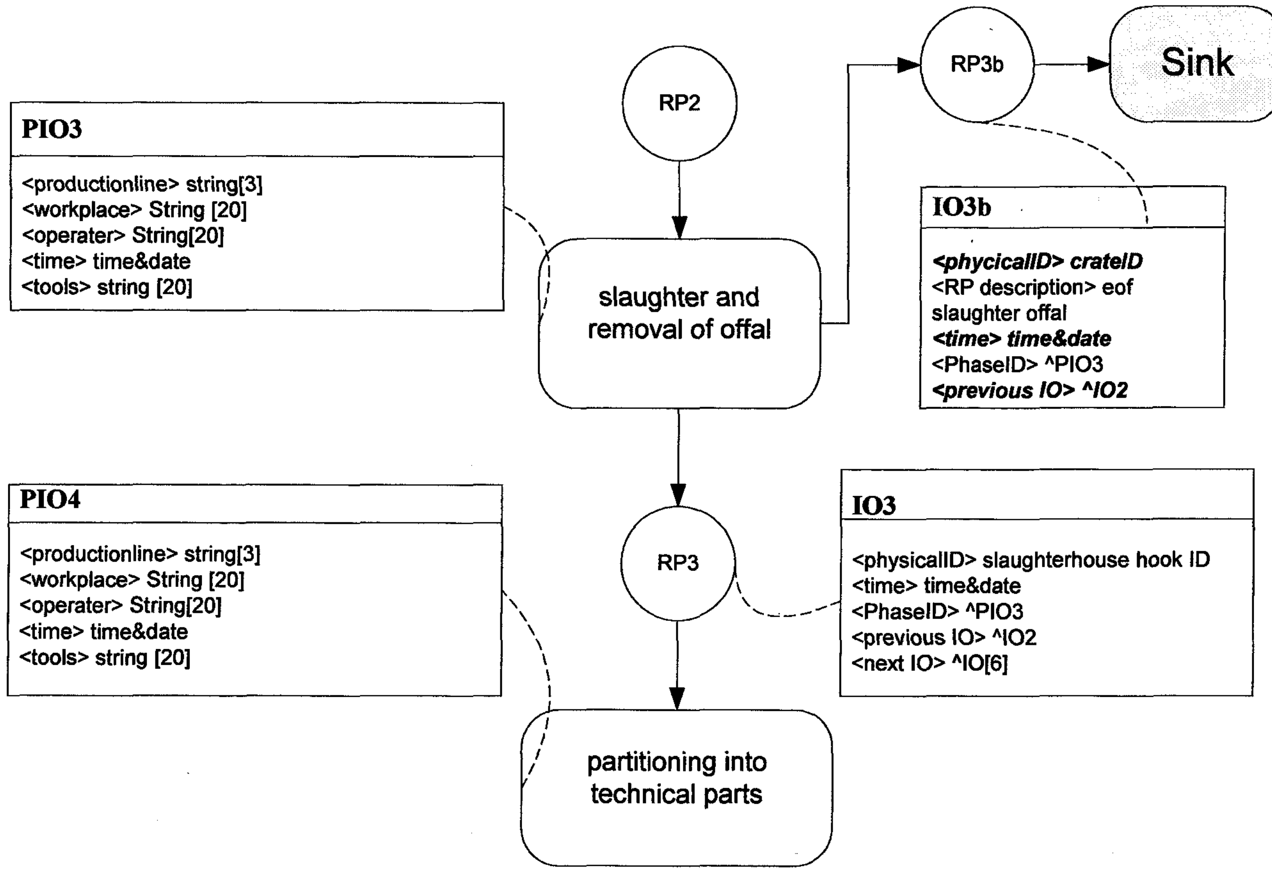

Figure 3.4 Adjustments to current model of the pork chain, based on the second question

3. How can we diminish the volume of a recall?

Current situation

The minimum volume of a recall of product depends on the moment in time a problem in the production chain (e.g. a contaminated ham) is detected. We consider the following moments in time:

- **The moment the slices of ham are already in the supermarket**

At this moment in time the minimum volume consists of the tumbler batches that are processed during a certain time on a certain day for a certain customer. These tumbler-batches consist of numerous hams that consist of numerous pigs. Hams are not identified.

- **The moment the bundle of hams is attached to the conveyor hook**

At this moment in time the minimum volume consists of all the pigs that are processed in the slaughterhouse during a certain time and date.

- **The moment after the tumbler is filled with an amount of hams**

At this moment in time the minimum volume consist of all the hams in a tumble-batch. This comes down to numerous pigs.

Desired situation

The problem of the unidentified conveyor hook has already been tackled in the first question. The result of this is that an individual ham can be identified and it is known of what pig the ham originates. To downsize the volume of a recall at all of above-mentioned moments our attention is drawn to the phase of tumbling. To improve the current situation the size of a tumbler-batch needs to be minimized. A certain amount of identified hams need to be tumbled during a certain time. Hams tumbled during a certain time period is called a batch of hams. It can be registered what hams are in a batch. To downsize these batches also adjustments to the process structure might be needed. Right now the tumbling phase is established as a bulk-process. Large amounts of hams are inserted in the tumbler all at once.
On option is to establish multiple lines of production existing of smaller tumblers. Another option is to establish the tumbling phase more as a continuum process. Hams are partially tumbled and led into the next tumbler until the tumbling phase is finished. In this way combined with a precise time registration smaller batches can be followed.

Implications to the model

The tumbling phase has to be split in multiple phases. Tumbling-phases follow each other or are progressed in a parallel to each other. PIO7 needs a time-registration attribute.
Figure 3.7 depict the adjustments that had to be made to the model in order to come towards answering the third question when we choose for parallel placed tumblers. Similar adjustments are needed to place tumblers serially.

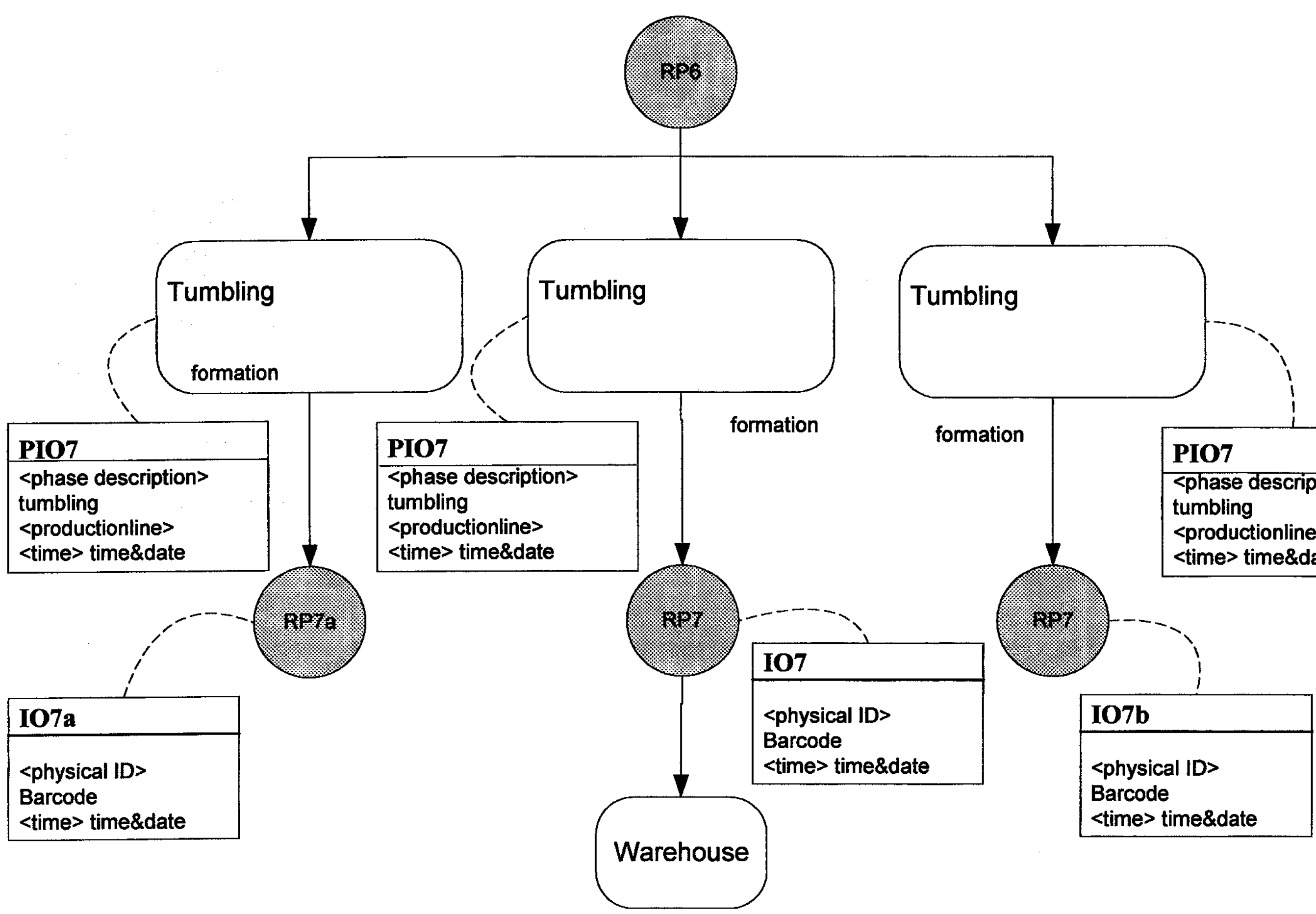

Figure 3.5 Adjustments to current model of the pork chain, based on the third question

3.4.2 Modeling towards the desired situation in the pear chain

First we repeat the question clients wanted to be answered in the pear chain.
We pursue with answering the questions one by one, by discussing the current and desired situation and the implications to the model of the pear chain it would take to model a desired situation.

1. **Is it possible to find out from grower the pears originate that I bought at the supermarket today at 5 p.m.?**

Current situation

In the current situation the first question can be answered. In the first place because to the crates of pears in the supermarket a physical ID is attached, which contains the growercode, pointing to the grower the pears originate from. Also the pears in consumer packages can be traced backwards in the chain to the grower. This, however takes some rework because a growercode is not physically attached to the consumer package. The growercode can be discovered in the packing company. In the packing process it is registered what pallet, identified by a growercode is processed into consumer packages. This is known due registering which pallets were unpacked and packed into consumer packages during a certain time-interval.

Desired situation

To eliminate the rework that has to be done to make it easier to trace back consumer packages to the grower, a growercode needs to be physically attached to a consumer package. The same applies to the pears that are sent out of the pear chain due to insufficient quality, although this means an extension to the posed question..

Implications to the model

The model has sufficient functionality to answer the first question. However, adding a physical to IO6 and IO5b, will adjust to the desired situation mentioned above.

2. **Can a T&T system be used to stress the benefits of a biological production method?**

Current situation

As it is now, the consumer in the supermarket cannot determine the particular product features and origin of pears, which are important aspects for marketing purposes. For example the average consumer is unaware of how a biological method of growing pears can be distinguished from a 'normal' growing method. The benefits of a biological growing method are not made visible to the consumer, when purchasing a pear.

Desired situation

Companies in the pear chain want to be able to differentiate themselves from competing companies by stressing the particular quality of their pears and the reliability of the supply chain the pears travel through. Therefore information about the processes in the pear chain and the pear itself has to be made visible to the consumer in the supermarket. Linking this kind of information to the barcode that is attached to pear's package in the supermarket might achieve this visibility. For example, in a future situation a consumer can access to information about the biological method of growing, by scanning the barcode of the pear's package in a machine of information-pillar in the supermarket. Output of the machine will be information about the pear and the specific product features and production methods that were used.

Implications to the model

To implement above-mentioned functionality, in the model of a T&T system in the pear chain, a physical ID has to be added to IO6.

3. Can a T&T system make that when a product leaves the warehouse or retail-outlet this is also noticed at the packing company?

Current situation

In the packing company we visited, this can be noticed. At the warehouse pallets still have a barcode. Barcodes are scanned and using an information system based on Electronical Data Interchange (EDI) it can be determinated which pallets leave the warehouse. This information is linked to the packing company that can react by a sending a new load of pallets, when the warehouse in low on supply.
In another company we visited in the pear chain, no barcode but growercodes are attached to pallets and crates of pears. Communication from this company to the warehouse is not yet automated, but warehouses are being delivered periodically.

Desired situation

A disadvantage of the way of identifying pears that is used in the second company in the pear chain is the fraud-sensitiveness. When barcodes that can only be read by scanning, fraud might be diminished.
This might be desirable in a future situation.

Implications to the model

Physical ID's can only be barcodes.

Adjustments made to the model of the pear chain are represented in Figure 7 and 8 of the appendix.

4. Simulation

The simulation package Enterprise Dynamics (ED) can simulate chains. Thereto a number of objects (in ED called atoms) are part of ED that can serve as the different phases in a supply chain. These objects are a source, a sink, a server (represents an operation) and a queue. A product-atom represents the product that travels through the chain. The objects in ED can be interconnected to form the product flow in a supply chain. Products can be labeled. A data-recorder atom can be linked to an atom to register information about what happens inside an object. In the future the functionality of ED can be used to construct the information flow in the chain.

Using the initial functionality of ED it is not possible to simulate models of T&T systems and thereby evaluating TraceTool. During this research simulation appeared to be a tool that doesn't (yet) posses the functionality to perform this task. However, the possibility exists to insert an Information Object (IO) in the simulation package to make a beginning simulating the information flow of a T&T system. This can be done by assigning the datarecorder-atom to act as a Registration Point (RP) and connect it to the atom of which information has to be registered. The user can indicate the number of variables, the reference (link) to the previous IO and to what atom the user wants the RP to be linked. Figure 4.1 depicts the choices that can be made by the user in a pop-up screen. Figure 4.2 depicts the table that represents the IO containing the information the user chose. Figure 4.3 depicts a screenshot of the RP (represented as a recorder) and an IO attached to the RP in between atoms in a simulation of a supply chain. Phase Information Objects (PIO's) were not included in the simulation. It took to much time to implement PIO's in the model and it doesn't contribute to the core of our study. The actual behavior of the information flow i.e. working links to PIO and IO's is not yet reached. It is expected that in the future the behavior of the information flow can be inserted in ED. This requires further programming and studying of the possibilities of ED.

Concluding, we see possibilities to simulate T&T systems in ED. At the present time Maarten Batterink, a student of Agricultural Systems Engineering at Wageningen University is working to extend the functionality of ED to include transportation processes with varying temperature during transport. However, due to our research ED is already extended with a RP connected to tables that contain the information of an IO. Also we are convinced that simulating in ED is only a sub-objective in our research, because evaluating TraceTool can be done by modeling cases as done in chapter three. We found that we were able to model and analyze T&T systems without simulating the models in ED.

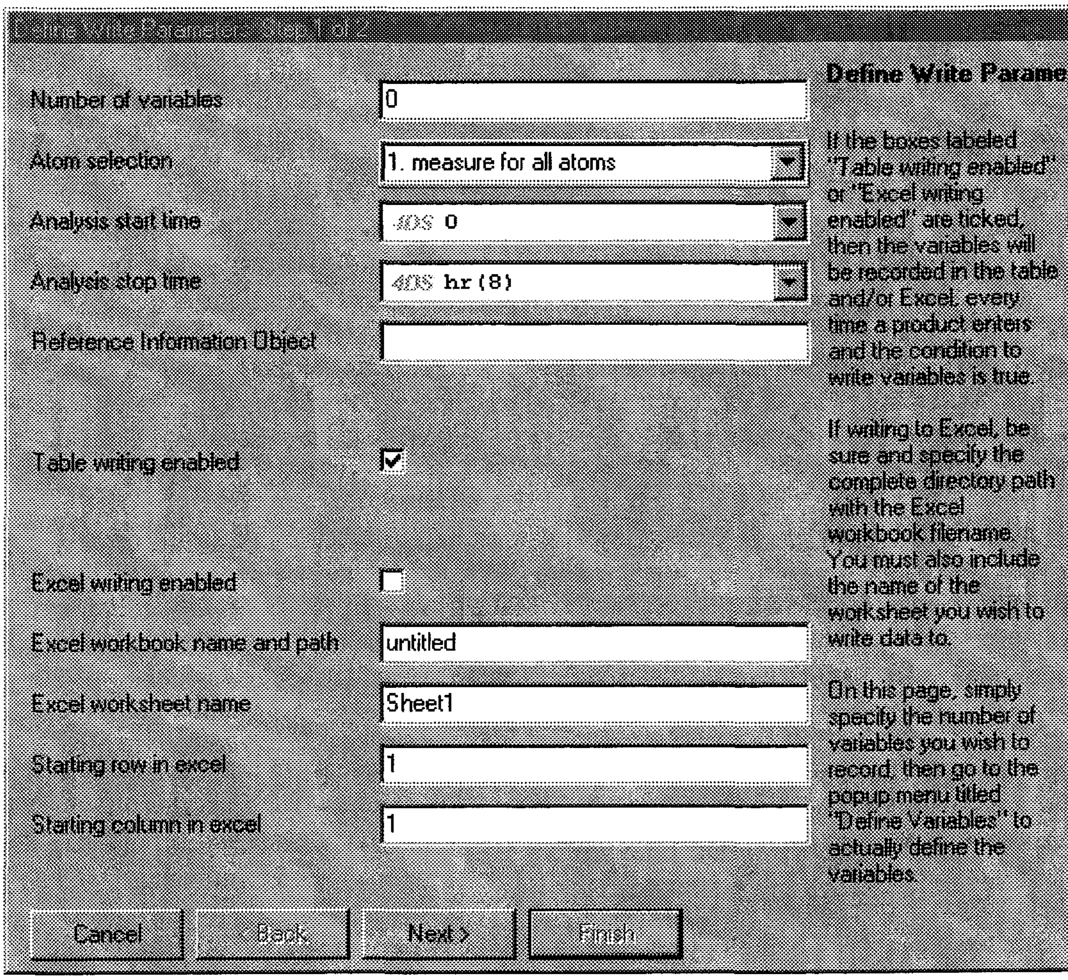

Figure 4.1 The choices that can be made by the user, registrating information in an IO

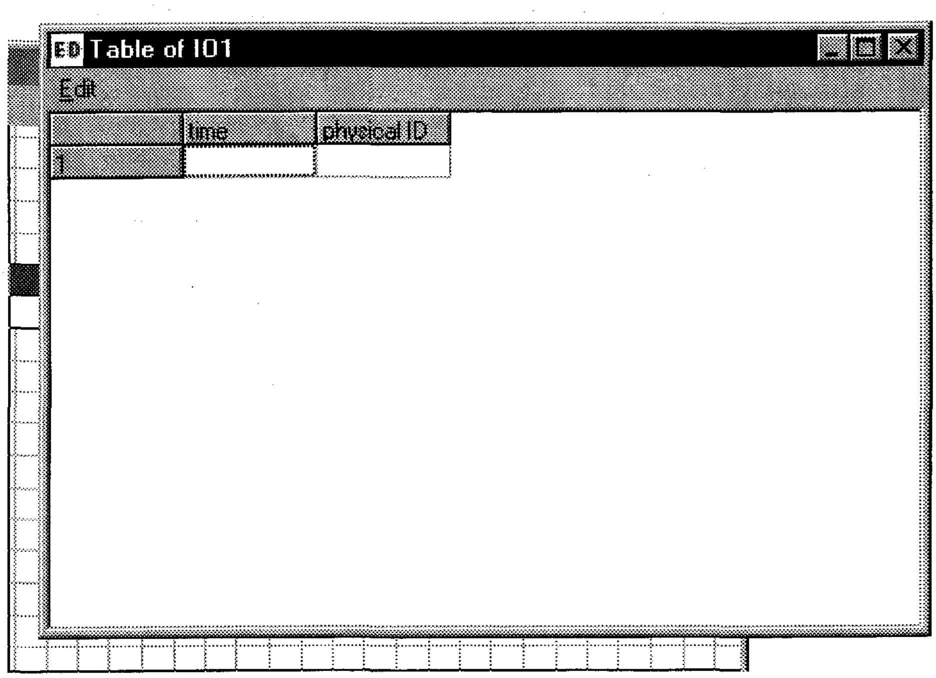

Figure 4.2 Table of an IO showing variables inside an IO

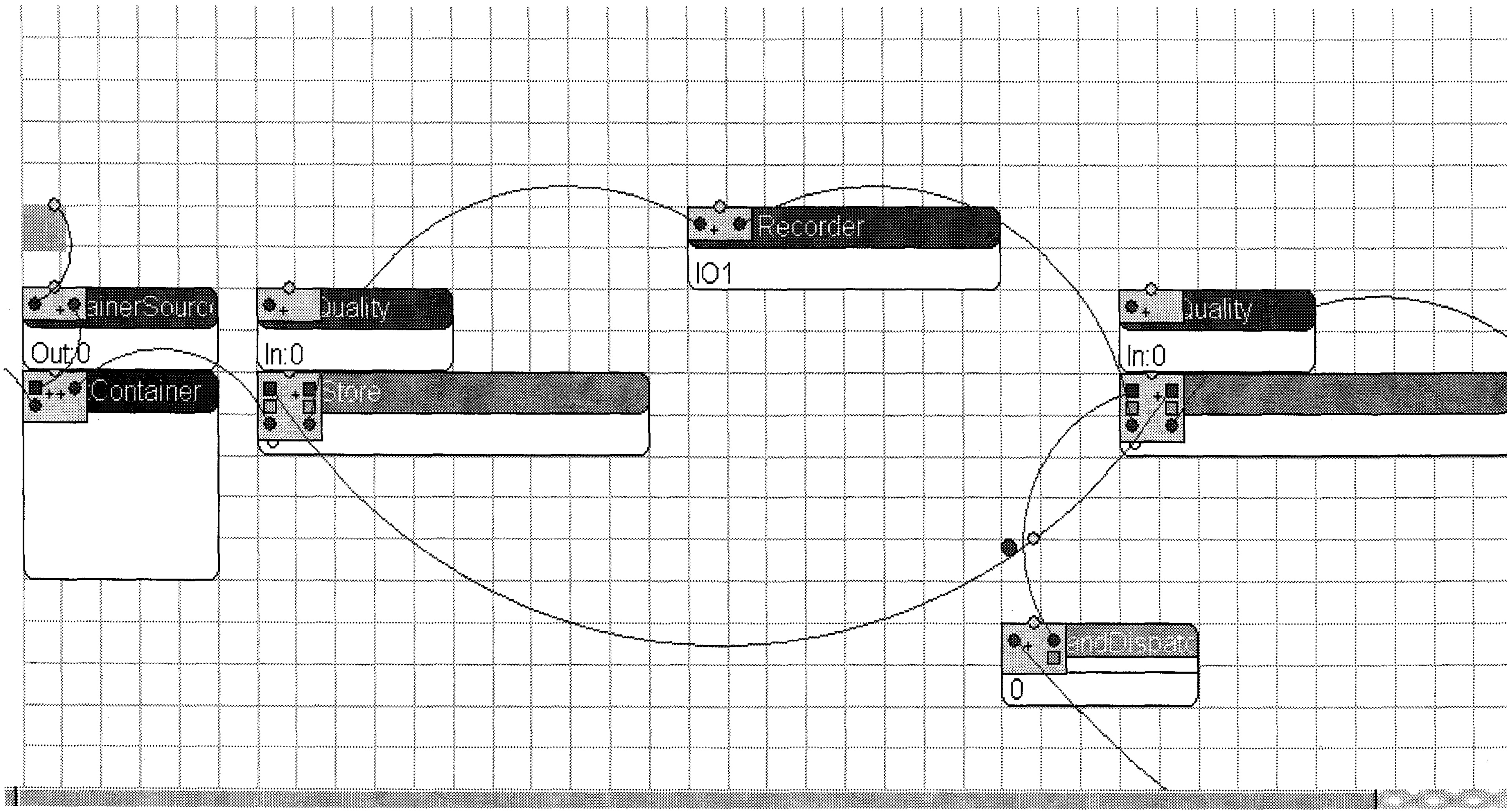

Figure 4.3 Screenshot of simulation

5 Evaluation of TraceTool

At the start of this research the TraceTool modeling method was still under development. Little was known about the usefulness of TraceTool. This research aimed to further develop and evaluate the TraceTool modeling-method. In this chapter we will evaluate our findings concerning TraceTool. In general we were able to model both cases and to analyze chains for bottlenecks. Also it proved to be possible to design improved models of T&T systems. We will evaluate in more detail upon the modeling language defined in TraceTool, the determination of client's demands and the necessity of simulation.

Modeling language

- Early in the research an extension was made to the concepts in the modeling language. While modeling the current situation of the pork chain in section 3.3, it was notice that the modeling language lacked a concept with the functionality of a concept that links the IU to an IO. Therefore the concept of a physical ID was designed. A physical ID is a tangible tag attached to the IU and provides a link to information stored in an IO, at the moment in the chain an IU passes a RP. The concept of a physical ID was added to the modeling language (in section 2.2), which is defined in TraceTool.

- Furthermore it was decided that in the modeling language phases are alternated by RP's. This implies that when an IU is gone through a phase in practice a RP has to follow in the chain. When a phase is not followed by a RP we have to design a virtual RP that for now only exists in the model, storing default information in an IO. This default information consist of the following three fields:
  (1) A RP description that tells the user where the RP is situated in the chain.
  (2) a pointer to the corresponding phase. This pointer is default, since it is known what phase was preceding a RP.
  (3) A pointer to a previous IO. This pointer is default, since it provides the link to information stored in previous IO's and thereby establishes traceability of an IU.

  Furthermore, a physical ID field is included in most IO's. A physical ID is included in the model when a tag is attached to the product in the T&T system.
  Also a time or date is present in most IO's. A time and date is added to an IO to register the time and date when an IU passes a RP. A time and date in an IO is obliged when the PIO the IO is linked to contains changing external factors over time. For example, in Figure 3 of the appendix time and date is included in IO3 of the pork chain to link to information in PIO3 about what operator slaughtered the using which tool etc. during what time. The time-interval that has to be viewed in PIO3, comes from IO3. It is the time-interval that is registered in RP3. In IO5 in the pear chain (Figure 8 appendix) no time or date interval is included because in PIO5 no information is stored about external factors that change over time.
  Information in PIO's consist of external factors that is included in the PIO, dependent on the demands of the client.

- A difficulty in modeling the current situation in the pork chain (section 3.3) occurred, when information about a pig was registered when it leaves the farm. In practice information about a pig is registered at the farm that the pig originated from. At the farm this information is attached to the pig in a UBN code. In practice pigs originating from different farms are loaded into the same truck and transported to the slaughterhouse. This implicated to the model of the current situation in the pork chain, that there had to be more than one farm representing the multiple farms pigs originate from, followed by multiple RP's in the model. In Figure1 of the appendix two farms are modeled followed by two RP's. This is arbitrary, since the number of farms and RP's can be less or more than two. In the model of the desired situation in the pork chain this part of the chain in modeled in a different way. This model includes a single farm together with a single RP in the model. In the RP pigs originating from different farms can be registered. It is just a different way of modeling.

- No phase primitive operation was included in the cases. This is caused by the cases we selected. In the cases we selected no operations changing the internal structure were included. However cases can be thought of that need a phase primitive operation. For example in the pizza chain at the point the pizza is heated in the oven and the internal structure of the pizza is changed. Therefore the phase primitive operation still has to remain part of the modeling language.

Demands of the client

A T&T system should arise from preset business goals of the clients. In practice clients have difficulties to express their business goals into requirements on a T&T system. In this research the business goals of clients could be specified using the general set of motivators to implement a T&T system, listed as reasons to implement T&T in section 1.1.1.
The demands companies (clients) have with respect to a T&T system had to be operationalized to requirements the T&T system has to meet. Examples of such are listed in section 3.2 and answered to by modeling the adjustments that are made to the initial models of the current situations. In this way T&T systems are modeled that answer to the reasons for T&T and thereby answer to possible business goals of clients. In the future it is preferable to include the real demands of the clients. This is expected to take some extra work, but in our view it will improve the truthfulness of TraceTool.

Simulation

The simulation package ED, in which we attempted to model chains, does not yet include all functionality to build T&T systems that we modeled using TraceTool. However we studied some of the possibilities of the ED-simulation package. It was found that a data-recorder atom could represent an RP. In this data-recorder a table can be created containing information that should be stored inside an IO such as a physical ID together with a time and date defining when an IU passes the data-recorder (visualized in Figure 4.2). Also it was found, as visualized in the popup-screen in Figure 4.1, that the possibility exists to add to an IO: a reference to another PIO or IO. (in the fifth editbox from above). Further programming is need to extend the functionality of ED. In our study simulating chains in ED could not contribute to evaluate TraceTool.

6. Conclusions and Recommendations

6.1 Conclusions

We will discuss the main findings of our research by answering the three main research questions formulated (in section 1.4).

How are T&T systems described? What are the problems that often occur in T&T systems?

In order to give a description of the product flow and information flow in T&T systems, we read reports, interviewed company people and experts at ATO. Two cases were described in section 3.1: the pork chain and the pear chain. The pork chain was described mainly based on information gathered out of reports. It turned out to be difficult to describe the product flow and information flow in chains in detail, only based on written reports or interviews with experts at ATO. Therefore, in order to describe the pear chain it was decided, to pay a visit to companies that are part of a pear chain and interview company-people. Generally it appeared to be possible to describe T&T systems bases on the two selected cases. A limitation of the research is that only two cases were modeled. This is a narrow basis to perform the evaluation of TraceTool.

Some problems became clear right after the beginning of describing the chains. For example in the pork chain it appeared that the slaughterhouse and the meat processing company in the chain do not communicate with each other about information that is attached to the product. In this way important information for T&T is lost. Cooperation in the chain is of great importance to T&T. This problem and other problems are addressed to in section 3.4 by designing improvements.

Is it possible to model the two selected chains using the concepts of the modeling language, defined in TraceTool?

It appeared to be possible to model the two selected chains (in section 3.3), using the concepts of the modeling language in TraceTool. While modeling of the two selected chains contributions were made to the evaluation of TraceTool. Amongst other adjustments to TraceTool, extensions were made to the modeling language as described in Chapter five.

What are the conclusions we can draw with respect to the evaluation of TraceTool out of testing the models, described in concepts of TraceTool, in an iterative way?

Improvements to models representing the current situations of both cases could be made in an iterative process (in section 3.4). TraceTool helps to make visible where in a T&T system improvements have to be made. Accordingly, in section 3.4 it is shown that TraceTool contributes to making recommendations to improve real-life T&T systems.

While using TraceTool, determining the demands of the clients proved to be a difficult task. These demands should arise from preset business goals. We experienced that clients have difficulties defining their business goals. In our study, this problem is tackled by thinking of business goals of clients could aim at using the general set of motivators to implement a T&T system, listed as reasons to implement T&T in section 1.1.1. To conclude, TraceTool can be used to translate client's demands into improvement to models of T&T systems. However, the limitation of the method used in that we were not able to use the real demands of clients.

During this study simulation has not contributed to the evaluation of TraceTool. It is questioned whether a simulation, discussed in Chapter four, can contribute to the evaluation of TraceTool. The possibilities to do so might be present, but further development (programming) of the simulation tool is needed. Concluding, in our view simulating chains in a simulation package is not necessary to evaluate TraceTool. In our study we were satisfied conducting the evaluation of TraceTool by applying the TraceTool modeling-method to model T&T system in two cases.

Overall we can conclude that, despite some limitations, we were indeed successful in contributing to the evaluation of TraceTool by testing TraceTool on two selected cases. Therefore we are satisfied in the degree we reached our objective.

6.2 Recommendations for future work

We conclude this report with recommendations for future work on the field of Tracking and Tracing at ATO. The discussed limitations of the research will be used in this section to help formulate directions for further research.

Analyze more chains

We made a start evaluating and documenting TraceTool by modeling two cases. Future work should focus on the construction of a solid modeling method for modeling T&T systems. Applying TraceTool to more chains can do this. It is expected that while modeling more cases TraceTool will be extended and improved. Also, in the future it might be possible to combine TraceTool with other models. For example quality-degrading models, because these models can be input to the information about external factors that is registered in phase information objects (PIO's).

Determine real client's demands

When more attention is paid to include the real demands of the client, TraceTool is expected to become a more truthful modeling method.

Further develop the simulation package

When more work is done to further develop the simulation package (ED) simulation can be usable. For example, it can be a method to visualize multiple chains to clients and to show to clients the improvements that can be made to their T&T systems.

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Appendix

The model of the pork chain and the pear chain and represented side by side to examine the adjustments made. The current situation in the pork chain is represented in the Figures 1 and 2), followed by the desired situation in the pork chain in Figures 3 and 4.
The current situation in the pear chain is represented in the Figures 5 and 6, followed by the desired situation in the pear chain in Figures 7 and 8.

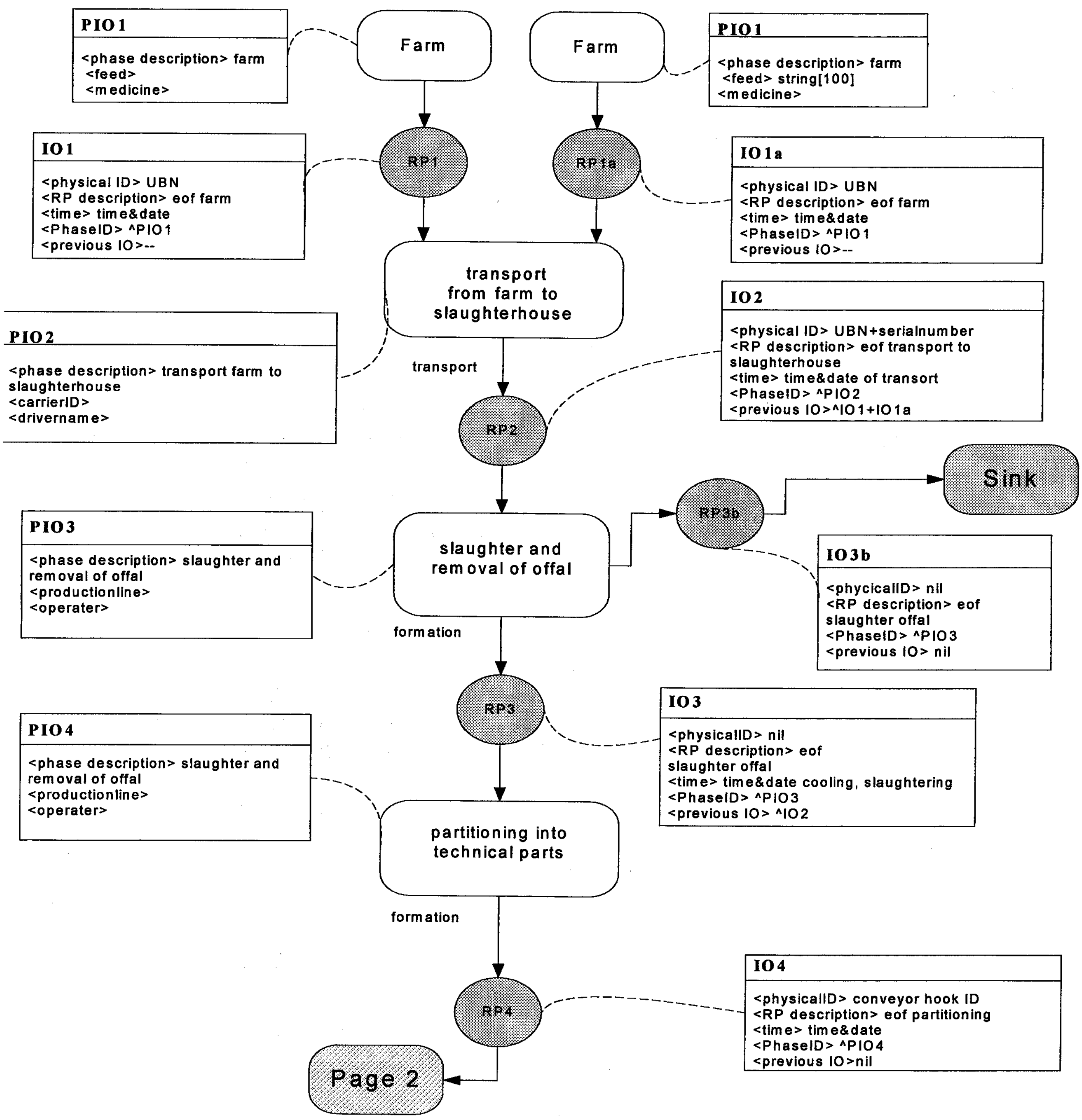

Figure 1 Model of the pork chain: current situation, first part

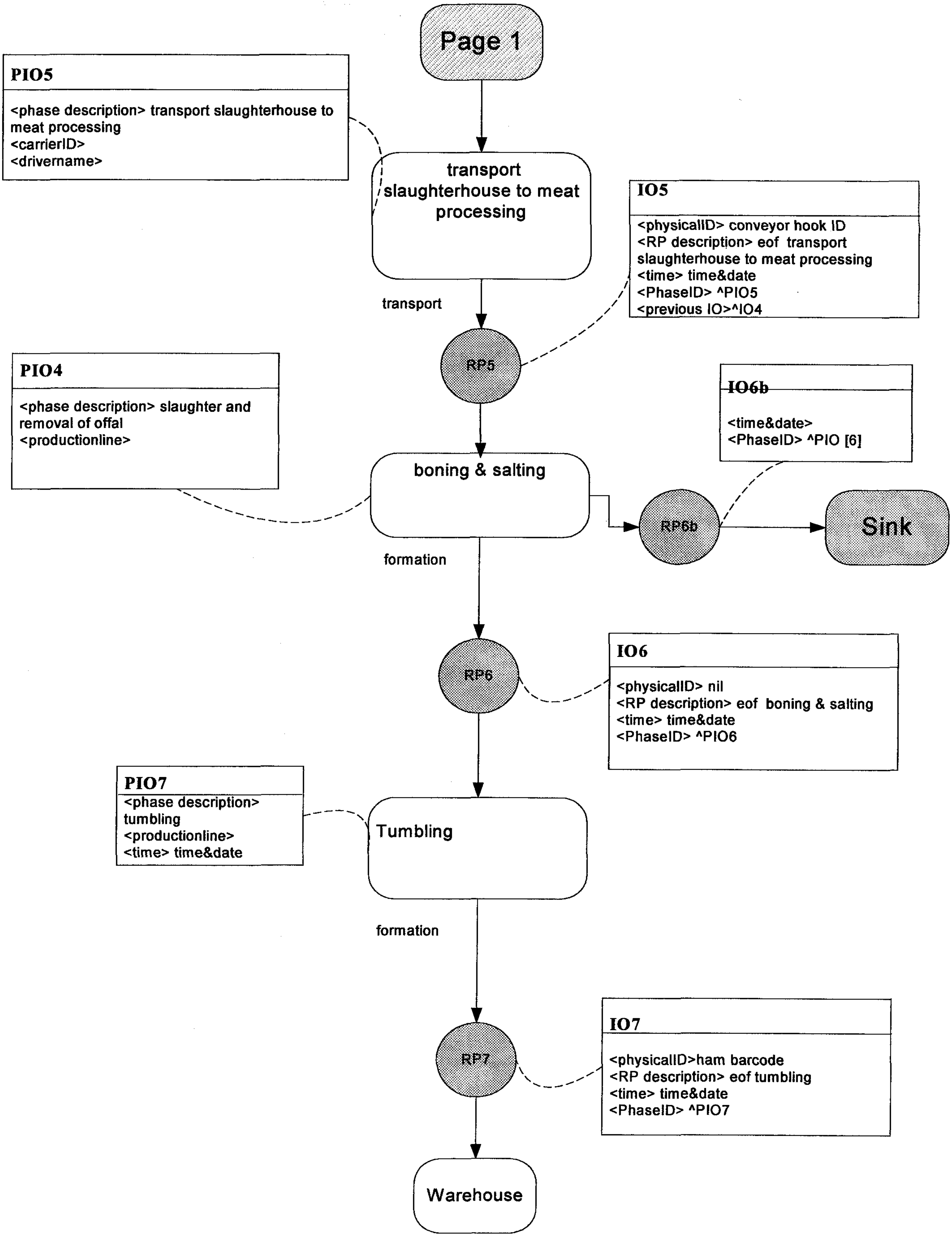

Figure 2. Model of the pork chain: current situation, second part

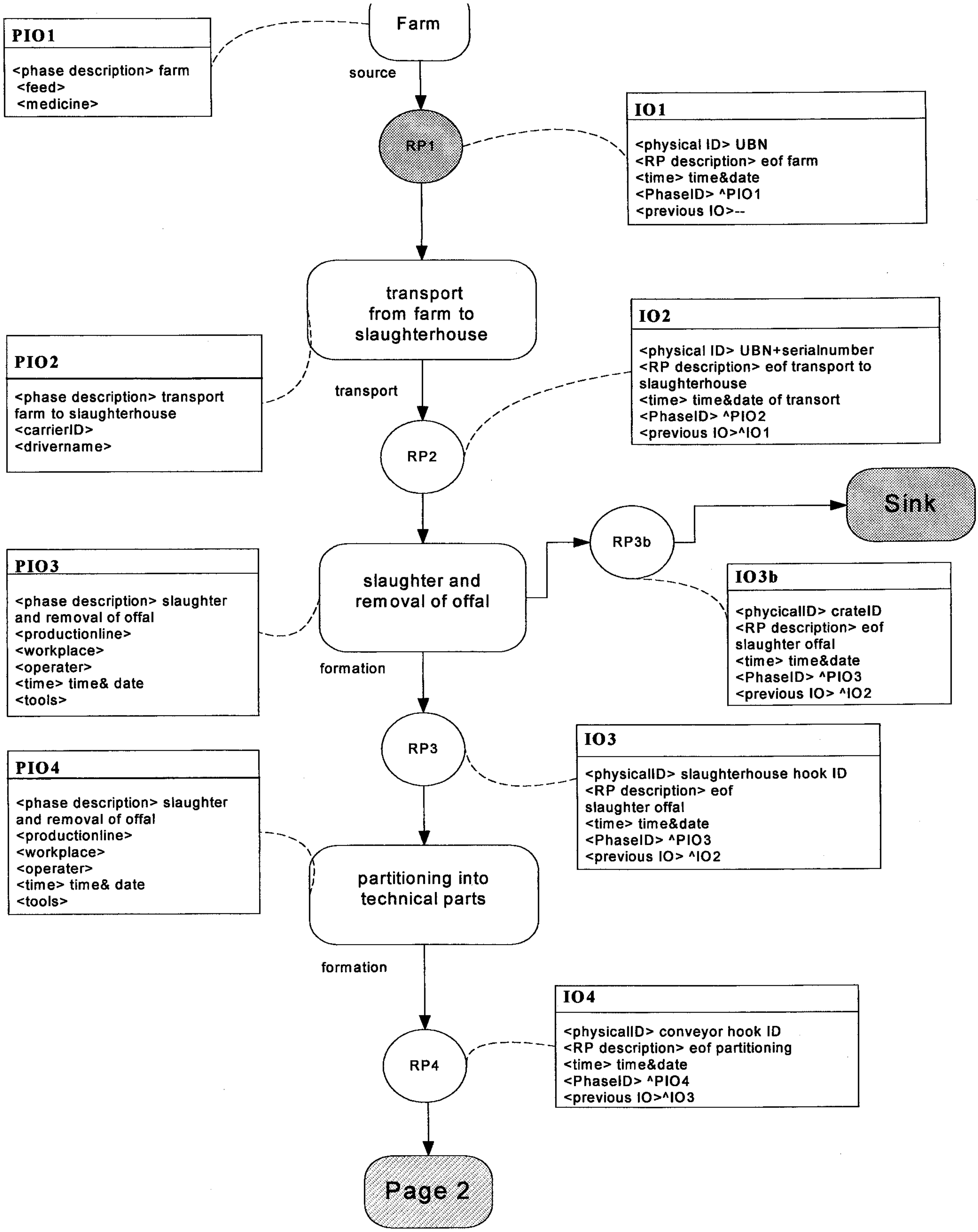

Figure 3 model of the desired situation in the pork chain, first part

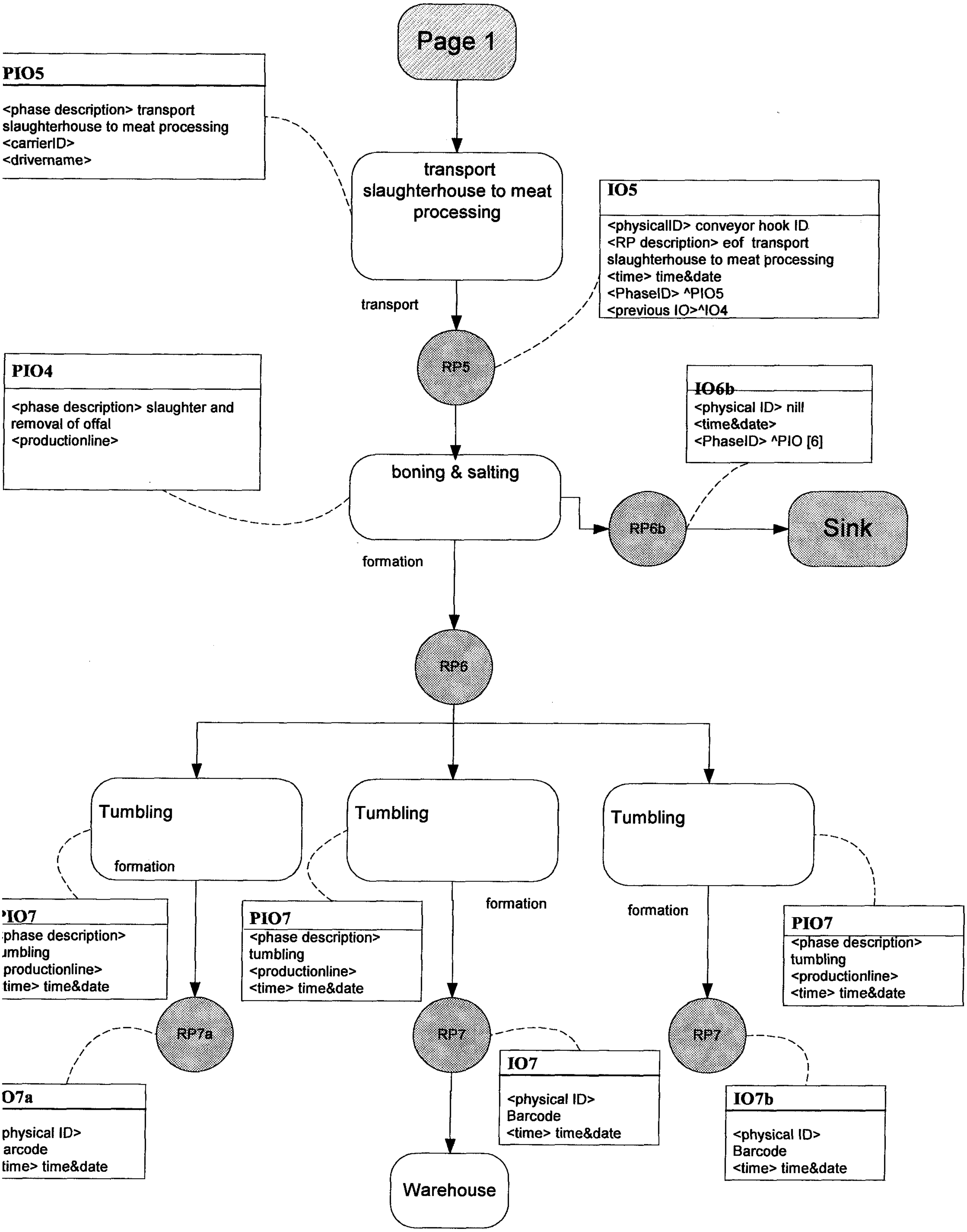

Figure 4 model of the desired situation in the pork chain, second part

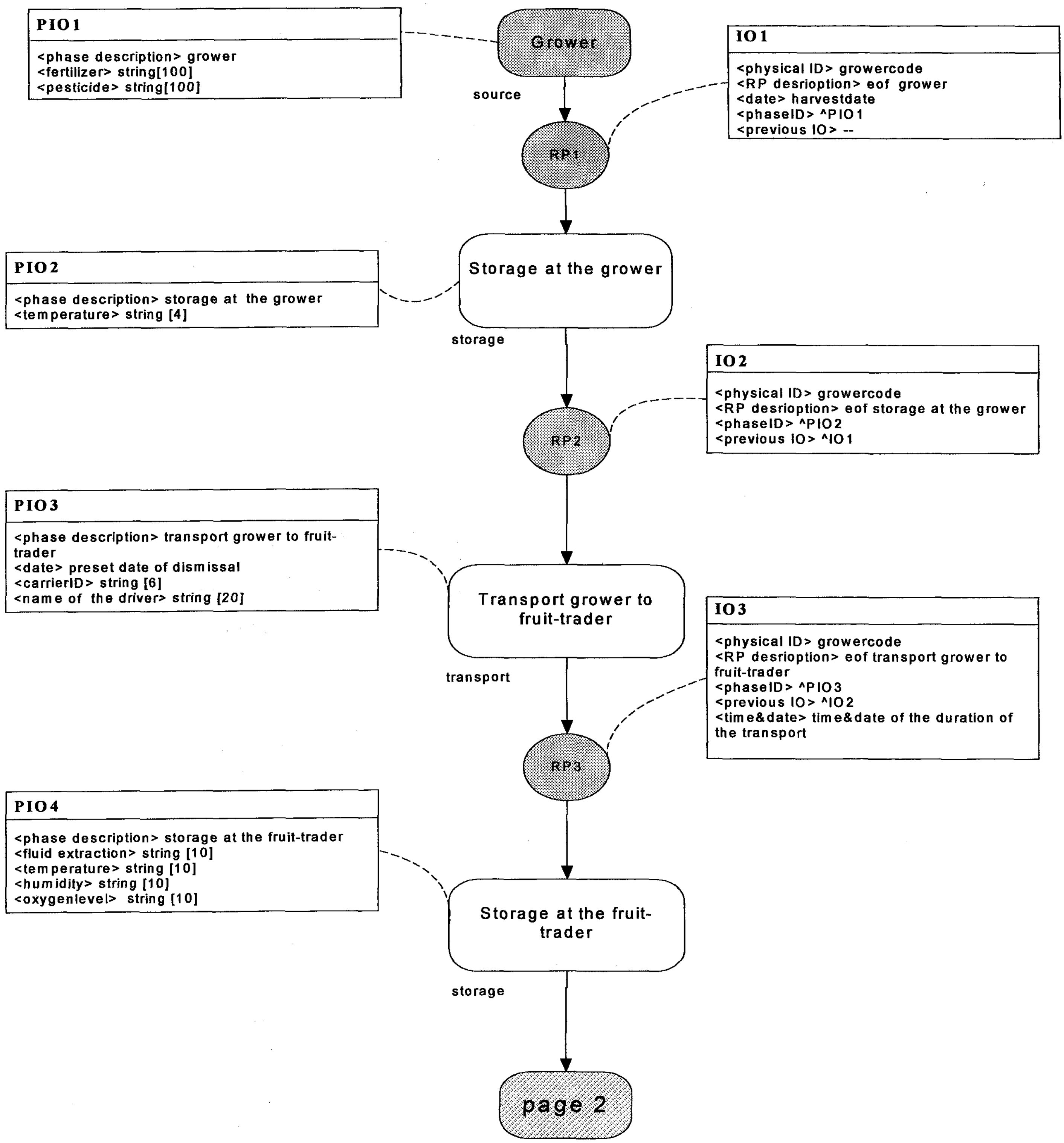

Figure 5 Model of the pear chain: current situation, first part

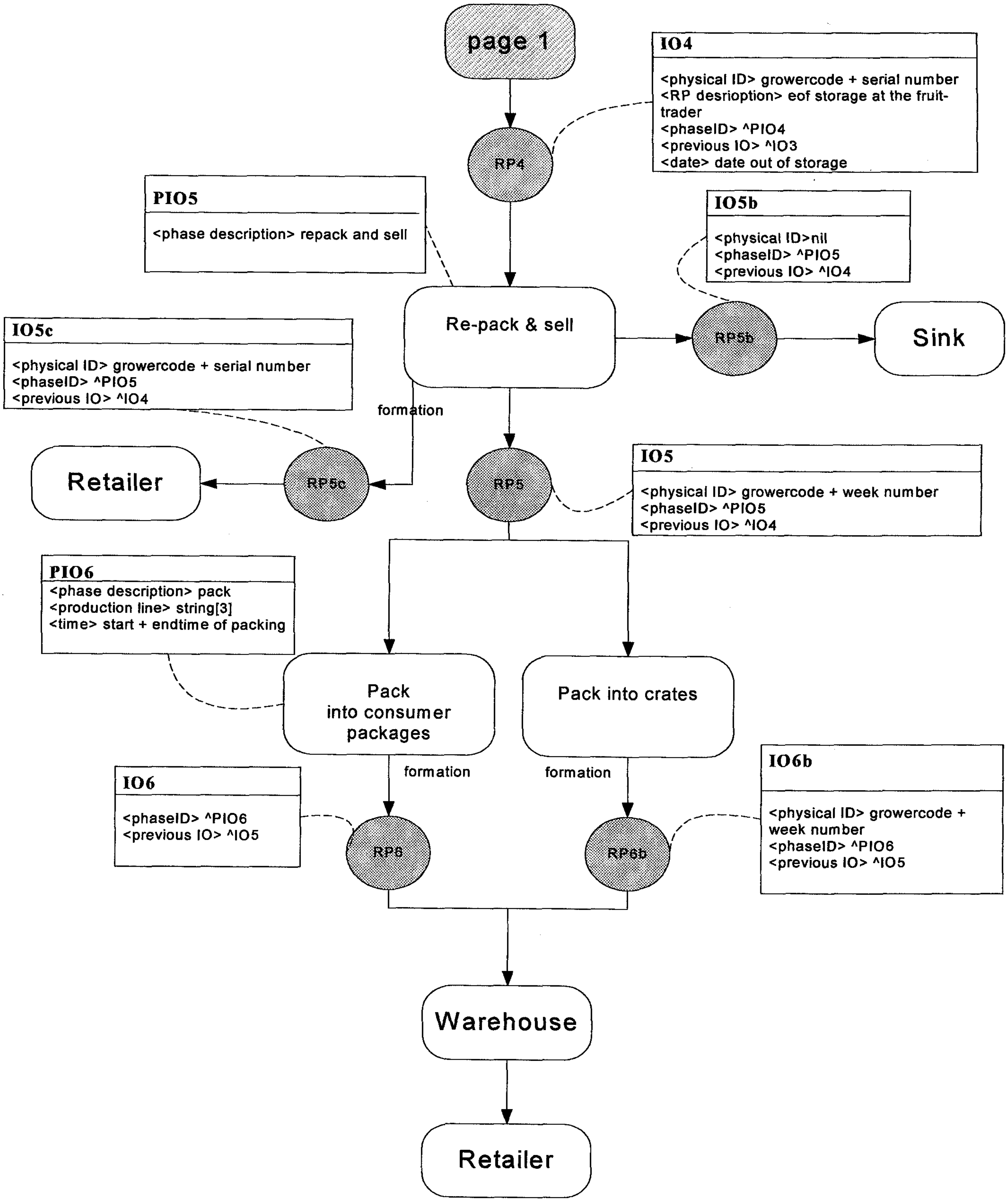

Figure 6 Model of the pear chain: current situation, second part

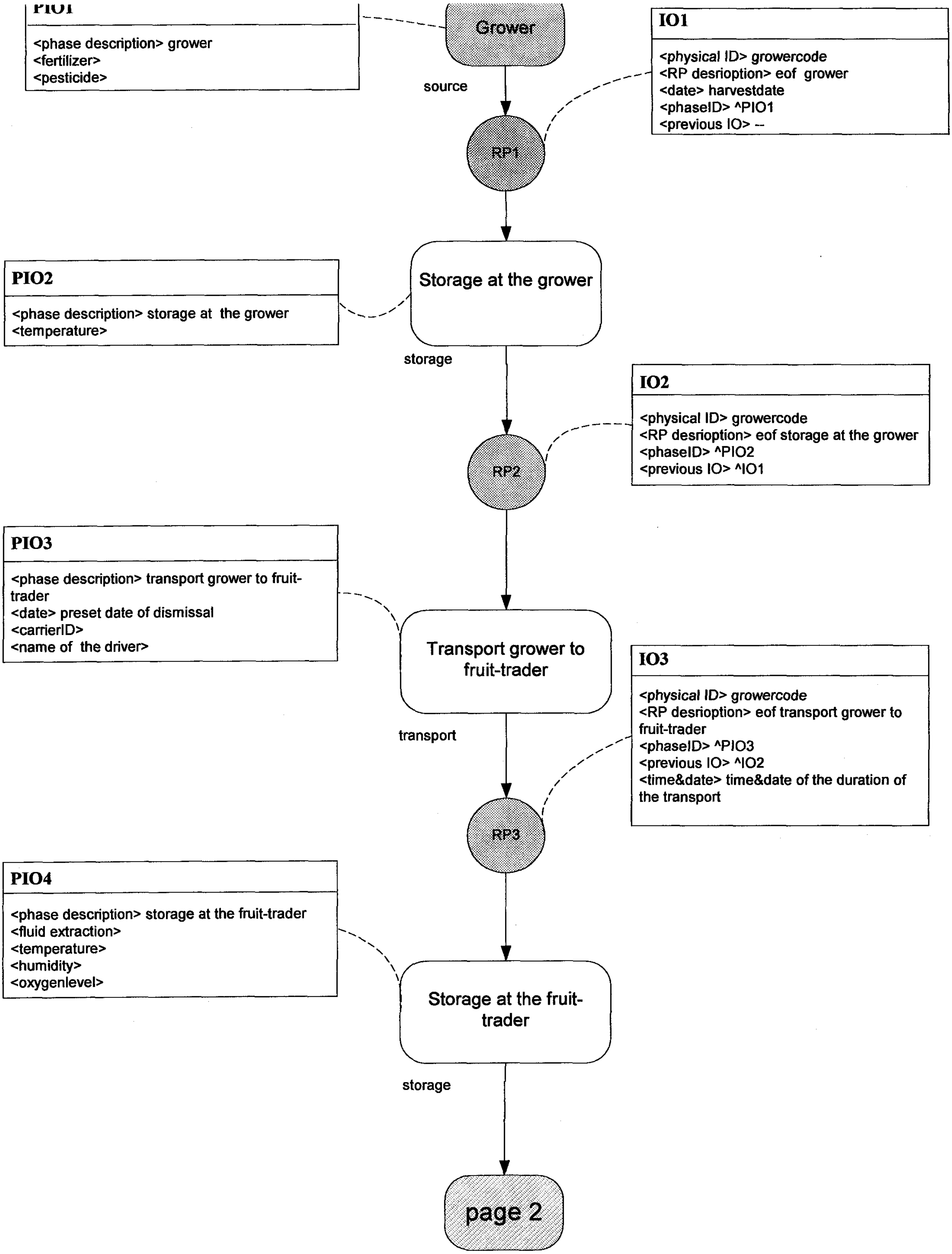

Figure 7 model of the desired situation in the pear chain, first part

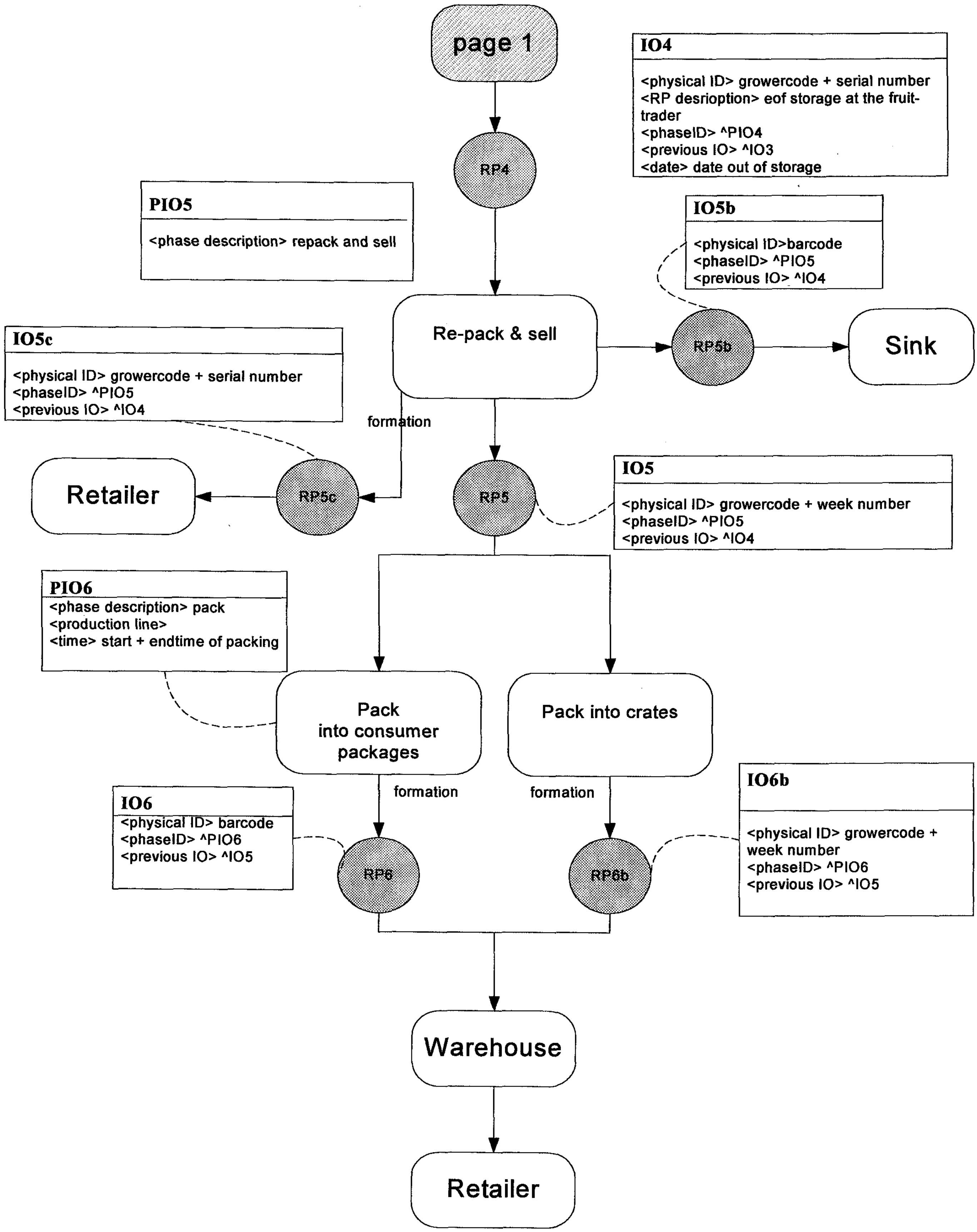

Figure 8 model of the desired situation in the pear chain, second part

Acknowledgements

I thank Nicole Ketelaars for supervising. Her comments were very constructive and it guided me to complete the research. Furthermore, I thank Jan Top and Floor Verdenius for letting me conduct this research and for coming up with creative ideas on how to pursue the research. I thank Kees-Jan van Dorp for supervising me and providing the report with scientific comment.